This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

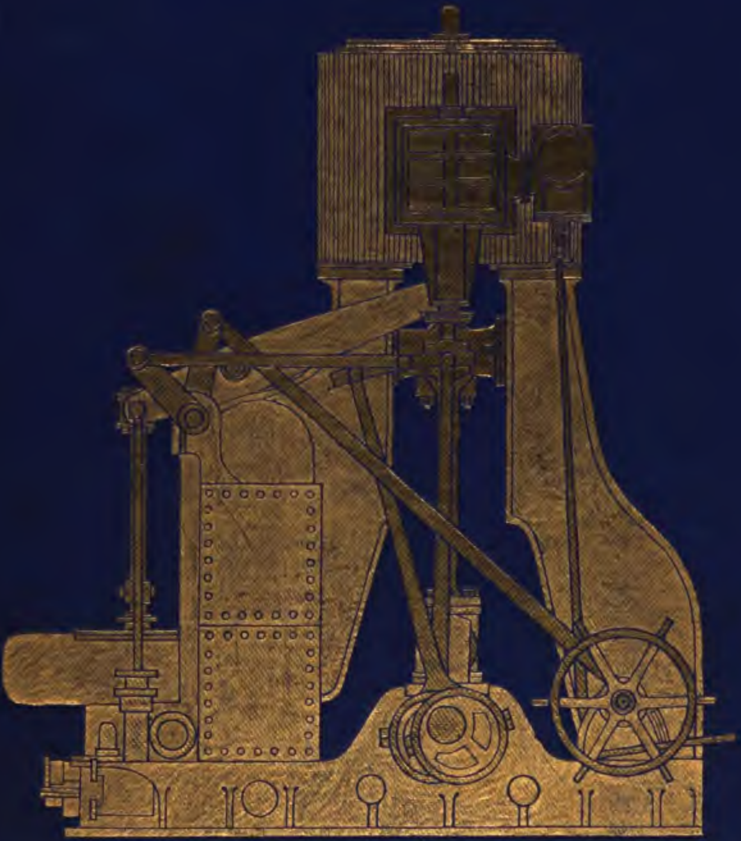
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

BERGEN'S



MARINE ENGINEER

7/-

BERGEN'S

MARINE ENGINEER.

BY

WILLIAM CULLEY BERGEN,

MASTER IN THE MERCANTILE MARINE,

AUTHOR OF "BERGEN'S NAVIGATION," "SEAMANSHIP,"
"GREAT CIRCLE CHARTS," &c.

PRICE 7s. BY POST 7s. 6d.

(Entered at Stationers' Hall.)

BIBLIOTHECA
MAY 1 80
BODLEIANA

NORTH SHIELDS:
PRINTED AND PUBLISHED BY W. J. POTTS & CO., ATLAS WORKS.
LONDON: SIMPKIN, MARSHALL & CO., STATIONERS' HALL COURT.
GLASGOW: D. McGREGOR & CO., CLYDE PLACE; ALSO SOUTH CASTLE STREET, LIVERPOOL.
LIVERPOOL: PHILIP, SON & NEPHEW, SOUTH CASTLE STREET.
SUNDERLAND: WM. C. BERGEN, LAWRENCE STREET.
1880.

186. e. 144.

NORTH SHIELDS:
W. J. POTTS & CO., PRINTERS, ATLAS WORKS, BEDFORD STREET.

PREFACE.

In the following work I have endeavoured to bring the questions before the students as plainly as the nature of the subjects will admit; my own experience as a teacher of Engineers strongly inclines me to think that ample explanations should be given to every question, and I have acted in accordance with that opinion.

As many of the questions are now proposed by the Examiners to the Candidates in an Algebraic form, I have given as much of the principles of Algebra as will enable the candidate to read and apply the formulæ with facility, and I have also freely applied the principle of cancelling where it can be used to shorten the solution.

In a few of the examination papers every figure required in the solution of the questions in those papers is put down, and afterwards the principal steps in the solution of every question are given.

To facilitate the understanding and working out, questions involving the weight of different parts of the steam engine, I have given wood cuts of those parts, so as to meet the requirements of Engineers, and to enable them to comprehend the form and size of the article of which they have to find the weight.

I have also introduced such drawings as will be good examples for both study and practice; those examples have in all cases been given at the examinations.

While writing this work I have had the assistance of some very experienced teachers, and skilful practical engineers, to whom I am much obliged for their very valuable help.

Some of the indicator diagrams were taken by a gentleman from different engines built on the Tyne and Wear, and the remainder were taken by him from the "Engineer" and "Engineering," by the kind permission of the Editors of those works, for which I sincerely thank them.

I venture to express a hope that Engineers, whether at sea or on shore, who are preparing for examination, will find in this work all that is necessary to enable them to pass a creditable examination.

Wm. C. BERGEN.

PART II.

Examinations of Engineers 1
Qualifications 2
General Rules 3
Certificates of Service 4
New Examinations. Notice 5
Examination Days 5
Hints to Engineer Candidates 7
Time and Marks 8
Signs used in this Work 10
Exercises in the use of the Signs 11

ALGEBRA.

Algebra 12
Equations 13
Numerical Values of Formulæ 13
Area of Rectangle 18
Area of Circle 19
Circumference of Circle 19
Rectangular Solid 19
Volume of Cylinder 20
Volume of Hollow Cylinder 20
Surface of Cylinder 21
Pumps 21
Tons of Water Lifted per Hour 22
Time in which a Pump will Empty a Tank 22
Time in which Two Pumps will Empty a Tank 23
Horse Power 24
To find the Pressure when Ship is Heeling 25
To find the Bolts in Cylinder Cover 25
To find the Tons of Injection Water used 26
The Lever 26
Volume and Height of Tank 27
Pressure per square inch on Boiler 27
Time Steam remains in Superheater 28
Steam Escaping 28
Height Safety Valve Lifted 29
Inches of the Air Pump full 30
Time that Pressure takes to rise 31

EXAMINATION PAPERS.

ARITHMETICAL QUESTIONS.

Notation. Numeration .... 34, 63, 66, 72, 135, 137, & 142
Quantities connected by Algebraic Signs .. 34, 41, 47, 52, 57, 75, 79, 90, 95, 104, 117, 120, 125, 132, 135, 137, 139, 142, 145, 149, 167, 170, 176
Addition of Vulgar Fractions 57, 120, 144, 170
Subtraction of Vulgar Fractions .... 40 & 129
Multiplication of Vulgar Fractions .... 40, 120, & 170
Division of Vulgar Fractions 135
Addition of Decimals .... 85, 144, & 160
Subtraction of Decimals 109
Multiplication of Decimals .... 40, 48, 63, 137, & 160
Division of Decimals 63
Compound Addition .... 35, 63, & 142
Compound Subtraction 63
Compound Multiplication 63
Compound Division .... 35 & 90
Bills of Parcels .... 74 & 95
Rule of Three .... 47, 58, 72, 74, 85, 135, 137, 139, 149, 157, & 160
Rule of Five .... 82, 85, 98, 126, 163, & 170
Wages of Men 67
Engineers' Bonus .... 35, 45, 46, 78, 104, & 145
Engineers' Per Centage .... 68 & 78
Alteration of Engineers' Wages .... 84 & 163
Amount of Wages .... 49 & 145
Consumption of Coals on Voyage 63
Tally of Baskets of Coals 73
Report of Fuel 70
Time that Ship will reach Port 74
Square Root 98
Speed of Ship and Rate of Cost .... 42, 43, 138, & 144
Baskets of Coals required 69
Gills of Oil used per day 73
Salvage 83
Loss through Engineers' carelessness .... 108 & 139
Kilo's of Tallow .... 115 & 172
Cost of Fire Bars .... 115 & 167
Babbet's Metal, how much can be made 122
Babbet's Metal, Price of 123

WEIGHT OF PARTS OF AN ENGINE AND OF METALS.

Weight of Iron Plate 72

Weight and Cost of Sheet Lead .... 56, 75, & 149

Weight of Gun Metal Liner .... 47 & 76

„ Piston .... 56, 75, 135, 143, 147, & 149

„ Slide Valve 60

„ Screw Shaft .... 69, 39, 78, 115, & 167

„ Screw Shaft with Bolt Holes 167

„ A T-Headed Piston Rod .... 104 & 150

Weights on Safety Valve 73

Weight of the Brass Casing on the Tail End of a Shaft 75

„ The Brass Lining of an Air Pump 75

„ A Pair of Brasses 76

„ A Thrust Block .... 80, 122, & 165

„ A Crank for a Paddle Shaft .... 77 & 92

„ Rim of Fly Wheel 157

„ A Cast Iron Ball 171

STRAIN, WEIGHT, FRICTION, FORCE, AND PRESSURE.

Strength of Rivets, Boiler Plates, and Seams .... 36, 102, 137, 141, & 146

Strain on Section of Stay .... 73, 132, 145, & 159

Length of Bearing .... 39 & 136

Effective Pressure on Piston .... 63 & 68

Boiler Pressure .... 44, 53, 122, & 135

Waste Steam Pipe .... 48, 118, 119, & 136

NHP .... 49, 132, 158, 159, & 169

HP .... 58, 97, 134, 145, 161, & 175

Pressure in Combustion Chamber .... 50, 33, & 163

Collapsing Pressure 50

Strain on Shaft .... 29, 52, 90, & 161

Strain on Rectangular Bar .... 130 & 173

Pressure of Steam on Safety Valve .... 132, 145 & 159

Pressure on Boiler Stays 68

Steam Blowing Off when Ship is Heeling .... 42 & 160

Steam Pressure and Revolutions of Engine 53

Strain on Bolts of Cylinder Cover .... 54 & 142

Force required to Break an Iron Bar 65

Weight on Supports of Girder, or Beam .... 80 & 165

Pressure on Plate in Combustion Chamber 81

Smallest Diameter of Stay 82

Strain on Sling Chain .... 87 & 173

What breadth must a Safety Valve rise to .... 88 & 174

Strain on the single part of a Rope .... 88, 89, & 174

Weight on centre bearing of Pump Lever 91
Breaking Weight on Red Pine Beam 93
Pressure on Boiler 94
Pressure on Piston 95
Tensile Strain on Piston Rod 96
Depth of Iron Bar 97
Strain per square inch on Iron Bar .... 97 & 173
Weight on end of Safety Valve Lever 98
Weight on Double Beat Valve 99
Total Pressure on Flat Bottom of Boiler 99
Pressure on Surface of Piston; find diameter 101
Drag of Friction; find H.P. 101
Drag of Friction; find per centage of loss 101
Maximum Strain on Iron; find depth at fulcrum 101
,, find pressure at end of crank 102
Pressure per square inch on Guide Block .... 105 & 150
Spiral Spring of Safety Valve .... 105 & 150
Loss of Steam and Coal in 24 hours .... 107 & 139
Weight of Water required to Condense Steam .... 107 & 140
Safe Working Pressure in Circular Boiler 110
Rivet Blown out of Ash Pit .... 113 & 171
Weight to break a Stud .... 113 & 171
To what Pressure would Steam rise .... 86 & 175
Pressure when Temperature and Height of Barometer are given .... 115 & 171
Balance Weight of Crank 117
Extra Strain, caused by a Boiler-stay breaking 121
Girth of Rope 123
Weight of Feed Water used as Steam per minute 125
To find the Pressure on the Valve .... 126 & 174
Three Cross Bunkers—How many tons go in the end Bunkers .... 127 & 168
Whitworth Thread; Strain on Bolt .... 130 & 157
Rectangular Lever Broken; required strain .... 130 & 159
Condensing Tubes Leaking in lbs. of Steam .... 131 & 158
Area of Water Level, and Weight of Coals Given, how far will Steamer sink 131
Efficiency and Weight of Steam per lb of Coal .... 132 & 153
To Find the Total Pressure against the Valve Face 132
Tons of Steam in 24 Hours 133
Atmospheric Pressure 134
Line of Perfect Vacuum 134
Least Consumption per I.H.P. 134
Weight of Water Evaporated during the Voyage 140
Area of Ship at Water Line, Tons taken in 151
Scale of Iron .... 151 & 153
Pressure Blowing Out Brine 157
Pressure Forcing Slide upon Cylinder 168

Force Applied to Handle, Wheel, and Axle 55
Weight to Stretch an Iron Bar 176
Engine Compounded, Ship Lengthened .... 118 & 176
B. T. Instructions. Circular Furnaces 176
Thrust on Surface of Screw Propeller 179
Loss of Work by Slip 179
Given Slip per Cent. to Find I.H.P. 179
Extra Weight if Bore be Full of Water 180
Loss by Friction 180
Correct Weight with False Balance 180
Torsional Strain on Shaft 182
Percentage of Strength of Longitudinal Seams 182
$P^1 + P^2$ Questions 183

NUMBERS, LENGTHS, REVOLUTIONS, BREADTHS, HEIGHTS, AREAS, AND VOLUMES.

Proportion of area of bolts to that of Piston Rod .... 34, 137, and 140
Rubbing Surface of Packing Ring .... 37, 138, & 141
Length of Two Side Bunkers 38
Square Feet of Felting to Cover Cylinders .... 45 & 160
Consumption of Oil 47
Coal Bunker .... 49, 58, 63, 111, 116, 136, 138, 142, 147, & 168
Revolutions of Engine .... 64, 131, 168, & 178
Pitch of Screw .... 64 & 125
Bolts in Cylinder Cover .... 66 & 147
Rivets in Boiler 66
Height of Tank 66
Cubic Feet of Steam used per hour 67
Oil from Top of Tank 72
Thickness of Screw Shaft Liner 76
Tons of Water Pumped into Boiler 78
Radius of Circle .... 79, 117, & 167
How much should be cut out of Packing Ring 87, 173
Thickness of Lead Wire 87, 173
Gallons of Water in 14 Tanks 90
Stay fastened by a double eye 91
Cable Tank of Telegraph Steamers 92
Heating Surface on Tubes and Tube Plates 99
Progression of Propeller; Rate of Ship 100
To find the time in which the pressure will rise 102
Slots in Steam Pipe 104, 149
Length of Shoe 108
Square feet of Condenser Surface per N.H.P. 109
Number of Tubes to Fire Grate 109
Cubic Feet of Steam Evaporated 109

Proportion of Area of Steam Pipe to that of Cylinder 110
Lift of Steam Valve 111
Area Valve is Open for Steam 112
Steamer Runs the Measured Mile 117
To find diameter of Cylinder .... 121 & 169
Bolts in Condenser Door .... 123 & 170
Exhaust Port Open 139
Travel of Slide 141
Height of Eye; Distance of Horizon .... 151 & 182
Thickness of Scale of Iron 152
Inverted Cylinder 156
Speed of Ship per hour 157
Paddle-wheel; How many knots will the Ship go .... 158 & 169
Square Feet of Fire Grate Surface 164
Strokes required to Draw off Cubic Feet of Steam .... 114 & 172
Length of Thrust Block ....
Connecting Rod Adjusted by a Screwed Cutter 175
Surface of Screw Propeller 178
Diameter of Circular Safety Valve Weight 180
Diameter of Nozzle of Injector 180
Stays Adjusted by Cotters 119

WORK DONE BY PUMPS.

Efficient Stroke of Pump .... 85, 96, 137, 146, 161, & 170
Time in Pumping Out Ballast Tank .... 52, 74, & 127
Capacity of Air Pump .... 59 & 135
Cubic Feet of Water Extracted in an Hour 64
Time both Pumps will Discharge Water Ballast .... 86 & 173
H.P. Exerted by Pump 120

TEMPERATURE.

Temperature of Funnel .... 36, 54, & 136
Temperature of Hot Well .... 54, 58, 136, 138, & 143
Temperature of Mixed Water .... 31, 79, & 162
How many Pounds of Circulating Water pass the Condenser 38
Tons of Injection Water Used per Day 55
How many Pounds of Water will be Required to Condense 1lb. of Steam? 55
Vacuum in Condenser .... 82 & 164
Vacuum Lowered, Revolutions of Engine .... 83 & 164
Boiler Water above the Feed Density 91
Fahrenheit Compared with Centigrade .... 95 & 163
Alteration in Temperature of Hot Well 164
Thermal Units of Heat .... 165 & 178
Latent Heat. Units of Heat .... 176 & 177
Air Heated, Required its Pressure 177
Temperature of Gases in Combustion Chamber 182

MISCELLANEOUS QUESTIONS.

Engine Counter ....118, 167, & 181
Saltness of Feed Water 118
Ship Lengthened and Fitted with Compound Engines 118
Size of Cotters.................... 118
Ratchet Wheel ....129 & 153
Proportion of Water Blown Off ....130, 157, & 181
Boiler above Feed Density.................... 162
Co-efficient of Efficiency 162
Power Varies as Cube of Speed.................... 184 & 185
What must Speed be to make Coal Serve 186
Diameter of Circle equal to sum of Decimals ....186 & 187
Maximum Strain on Crank Pin 186
In how many minutes will water in the Glass be out of sight 187
Weight against Thrust Block 188
How many Tons put into Bunkers, and Area of Section of Ship 188
Where does she Cut-off from Top 188
Pressure on Crank Pins 188
How much is a Hole below the Water level 189
Temperature of Mixed Water and Ice 191
What proportion of Feed should be Blown off 191
How many Tons Coals used in 6 hours Steaming 191
Density of Water in the Boiler 191
What Horse Power will Boiler work up to....................191
How many Tubes will you allow....................192

PART THIRD.

This part contains:—An Introduction. Answers to Elementary Questions. Verbal Questions. Work done by Pumps. Work done by the Steam Engine. Table of Hyperbolic Logarithms. To find the Mean Pressure throughout the Stroke. Explanations of the Indicator Diagrams. Wood Cuts. Engineer Drawing. Indicator Diagrams. Drawings of Parts of Engine.

PART I.

ARITHMETIC.

NOTATION AND NUMERATION.

The following figures are used to express numbers; the value of every number is placed underneath it.

0,	1,	2,	3,	4,	5,	6,	7,	8,	9.
nothing,	one,	two,	three,	four,	five,	six,	seven,	eight,	nine.

By the combination and repetition of these numbers, any number whatever may be expressed.

NUMERATION TABLE.

1	Units.
21	Tens of Units.
321	Hundreds of Units.
4 321	Thousands of Units.
54 321	Tens of Thousands of Units.
654 321	Hundreds of Thousands of Units.
7 654 321	Millions.
87 654 321	Tens of Millions.
987 654 321	Hundreds of Millions.
1 987 654 321	Thousands of Millions.
21 987 654 321	Tens of Thousands of Millions.
321 987 654 321	Hundreds of Thousands of Millions.
4 321 987 654 321	Billions.

Note.—Only the first figure of every line, counting from the left hand, is considered in the above table, the other figures are put in to keep the first figures in their proper places.

Read the number 2 222 222 222 222.

Note.—It is convenient to divide large numbers into parts containing six figures each, and to subdivide each of those parts into two portions containing three figures each. The first six figures, counting from the right hand, are units ; the second six are millions ; the third six are billions ; and so on.

Answer : Two billions, two hundred and twenty-two thousands two hundred and twenty-two millions, two hundred and twenty-two thousands two hundred and twenty-two.

Local Value.—The preceding number consists of a repetition of the number 2 ; the first, beginning at the right hand, represents two single objects, that is two units ; the second two represents two tens ; the third two represents two hundreds, and so on. Thus the number represented by it varies, according to its position. The value in a given position is called its *local value.* The cipher has no value by itself, but when it is placed to the right hand of significant figures it increases their value tenfold ; thus the number 20 represents twenty, the number 200 represents two hundred, and so on.

EXERCISES.

Express in figures :—

No.		Answer.
1	Seventeen.	17
2	One Hundred and Six.	106
3	Three Thousand and Seventeen.	3 017
4	One Million, Four Hundred and Twelve.	1 000 412
5	Eight Hundred Millions and Ninety-one	800 000 091
6	Five Hundred Thousand Millions.	500 000 000 000

Express in words :—

7—970 425 632 { Nine Hundred and Seventy Millions, Four Hundred and Twenty-five Thousands, Six Hundred and Thirty-two.

8—700 000 012 Seven Hundred Millions and Twelve.

Note.—By separating the figures into groups of three figures as above they are easily read.

SIMPLE ADDITION.

Simple Addition is the method of finding a whole number, which is called the sum, equal to two or more whole numbers added together.

Example.—Add 543, 749 and 542 together.

Solution.
543
749
542

Sum. 1834 Answer.

Proceed thus : Arrange the number as in the solution; namely, units under units, tens under tens, and hundreds under hundreds ; then the sum of 2 and 9 is 11, and the sum of 11 and 3 is 14; put down 4 in the units place of the answer, and add 1 mentally to the column of tens, or, as it is called, *carry* 1 ; then the sum of 1 and 4 is 5, and the sum of 5 and 4 is 9, and the sum of 9 and 4 is 13 ; put down 3 in the tens place of the answer, and carry 1 to the column of hundreds, then the sum of 1 and 5 is 6, and the sum of 6 and 7 is 13, and the sum of 13 and 5 is 18; put down 8 in the hundreds place of the answer, and 1 in the thousands place, and thus the sum is found to be 1834.

EXERCISES.

(1)	47347	(2)	67321	(3)	86432
	29563		54309		10054
	89432		74697		37697
	166342		196327		134183
(4)	394731	(5)	397432	(6)	789600
	564201		594764		431714
	463197		327820		524394
	542105		462073		671009
	1964234		1781589		2416717

SIMPLE SUBTRACTION.

Subtraction is the method of finding the difference of two whole numbers.

Example.—Find the difference between 32 and 18.

Solution.

32
18
14 Answer.

Place the lesser number under the greater, units under units, and tens under tens; then as 8 exceeds 2, *borrow* 10 and add it to the 2, the sum is 12, take 8 from 12, the remainder is 4, set down 4 in the units place of the answer. Again, as 10 was borrowed it must be returned by *carrying* 1 to the column of tens ; then the sum of 1 and 1 is 2, take 2 from 3, the remainder is 1, which set down in the column of tens ; this completes the answer.

EXERCISES.

(1)	From 9	(2)	From 343	(3)	From 5429
	Take 7		Take 171		Take 3072
	Answer 2		Answer 172		Answer 2357

(4) From 69742	(5) From 97432	(6) From 396973
Take 2946	Take 17401	Take 179042
Answer 66796	Answer 80031	Answer 217931

MULTIPLICATION.

Multiplication is a short method of adding equal numbers.

MUTIPLICATION TABLE.

1	2	3	4	5	6	7	8	9	10	11	12
2	4	6	8	10	12	14	16	18	20	22	24
3	6	9	12	15	18	21	24	27	30	33	36
4	8	12	16	20	24	28	32	36	40	44	48
5	10	15	20	25	30	35	40	45	50	55	60
6	12	18	24	30	36	42	48	54	60	66	72
7	14	21	28	35	42	49	56	63	70	77	84
8	16	24	32	40	48	56	64	72	80	88	96
9	18	27	36	45	54	63	72	81	90	99	108
10	20	30	40	50	60	70	80	90	100	110	120
11	22	33	44	55	66	77	88	99	110	121	132
12	24	36	48	60	72	84	96	108	120	132	144

The number which is to be added is called the *multiplicand*, the number which shews how often the multiplicand is added is called the *multiplier*, and the sum is called the *product*.

Case I.—WHEN THE MULTIPLIER IS NOT GREATER THAN 12.

Example.—Multiply 164 by 7.

Solution.
Multiplicand 164
Multiplier 7

Product 1148

Look in the first column of the table for the multiplier 7, then look along the upper line of the table for the units figure of the multiplicand 4, look in the column under 4 until it meets the 7th line, the number 28 is at the point of meeting, put down 8 in the units place of the product, and carry the 2. Again, look in the column under the next figure of the multiplicand, which is in the upper line, that is look under 6 until the column meets the 7th line, the number 42 is at the point of meeting, add the 2 which was carried to 42, the sum is 44, put down 4 in the place of tens, and carry 4. Finally, look under the next figure 1 until it meets the 7th line, the number 7 is at the point of meeting, take out 7 and add the 4 which was carried to it, the sum is 11, which set down as in the product.

The table is formed by addition ; thus, in the margin, 4 is added 7 times, and the sum is 28, and this sum is put in the table at the point where the column under 4 meets the 7th line. The whole of the table is formed in a similar manner. It is absolutely necessary for the pupil to commit this table to memory.

4
4
4
4
4
4
4
28

EXERCISES.

(1) Multiply 967
By 2
Answer 1934

(2) Multiply 5419
By 5
Answer 27095

				Answers.
(3)	Multiply	60317	By 4	241268
(4)	„	532614	„ 9	4793526
(5)	„	7149732	„ 11	78647052
(6)	„	4165431	„ 10	41654310

CASE II.—WHEN THE MULTIPLIER IS MORE THAN 12.

Example.—Multiply 542 by 471.

Multiplicand	542
Multiplier	471
	542
	3794
	2168
Product	255282

Multiply the multiplicand by 1, next multiply it by 7, and arrange the product as in the solution, finally multiply it by 4 and arrange the product as in the solution. Add all the partial products together, their sum is the total product.

EXERCISES.

No.	Multiply	By	Answer.
1	9176479	22	201882538
2	87643297	46	4031591662
3	47329007	541	25604992787
4	32164070	4001	128688444070
5	179643215	3294	591744750210
6	3004900	10040	30169196000

SIMPLE DIVISION.

Simple Division is a short method of finding how often one whole number can be subtracted from another. The number from which the other has to be subtracted is called the *dividend*; the number which has to be subtracted is called the *divisor*, and the number which shews how many subtractions there have been is called the *quotient*.

CASE I.—WHEN THE DIVISOR IS LESS THAN 13.

Example.—Divide 19 by 6.

Solution.

Divisor 6)19 Dividend.

Quotient $3\frac{1}{6}$

Look along the upper line in the multiplication table for the divisor, 6, then look in the column under 6 for the dividend 19, if it be not in the column take out the next less number, 18; then look along the line in which 18 is to the left hand, and in the first column there is the number 3, set down 3 in the quotient, subtract 18 from 19, the remainder is 1, put 1 down in the quotient, draw a line under it and put the divisor 6 under the line, these last two figures complete the quotient; and they will be fully explained when we come to treat of fractions.

The pupil may subtract 6 from 19 as often as he can; after 3 subtractions there remains 1, and the process is at an end; this agrees with the solution.

$$\begin{array}{r} 19 \\ 6 \\ \hline 13 \\ 6 \\ \hline 7 \\ 6 \\ \hline 1 \\ \hline \end{array}$$

EXERCISES.

No.	Divide	By	Answer.
1	697	3	$232\frac{1}{3}$
2	5439	4	$1359\frac{3}{4}$
3	7630	5	1526
4	1974321	9	219369
5	5000432	7	$714347\frac{3}{7}$
6	6978215	10	$697821\frac{5}{10}$

A *composite* number is composed of the product of other two or more numbers, which are called *factors* of the composite number.

CASE II.—WHEN THE DIVISOR IS A COMPOSITE NUMBER.

Example.—Divide 126 by 42.

Solution.

$$42\begin{cases}7)\underline{126}\\6)\underline{18}\end{cases}$$

$$\underline{3}\ \text{Answer.}$$

The number 42 is composed of the factors 7 and 6. Divide 126 by 7, the quotient is 18; again, divide 18 by 6 the quotient is 3, which is the quotient of 126, divided by 42.

EXERCISES.

No.	Divide	By	Answer.
1	84474	18	4693
2	764400	21	36400
3	10000000	5000	2000
4	3528	72	49
5	1728	144	12
6	7854	42	187

CASE III.—WHEN THE DIVISOR IS NOT A COMPOSITE NUMBER AND IS GREATER THAN 12.

Example.—Divide 5463 by 17.

Solution.

17)5463(321$\frac{6}{17}$ Answer.
51

36
34

23
17

6

Take the first two figures of the dividend, 54, as a dividend, then 17 is contained 3 times in 54 with a remainder 3, set 3 in the quotient. Bring the next figure, 6, of the dividend down, and take 36 as a dividend, then 17 is contained 2 times in 36 with a remainder 2, set 2 down in the quotient. Again, bring the next figure, 3, down, then 17 is contained 1 time in 23 with a remainder 6, set 1 down in the quotient, and the remainder 6, with 17 under it, as in the answer.

EXERCISES.

No.	Divide	By	Answer.
1	694325	374	$1856\frac{181}{374}$
2	7496274	4693	$1597\frac{1553}{4693}$
3	63974215	37694	$1697\frac{7497}{37694}$
4	743001400	543216	$1367\frac{425128}{543216}$
5	19400079	36400	$532\frac{35279}{36400}$
6	57200045	12464937	$4\frac{7340297}{12464937}$

REDUCTION.

Reduction is the method of bringing quantities of one denomination to another of equal value.

MONEY.

4 farthings = 1 penny.
12 pence = 1 shilling.
20 shillings = 1 pound.

Example 1.—Reduce £14 17s. 8¼d. to farthings.

$$\begin{array}{lll} \pounds & s. & d. \\ 14 & 17 & 8\frac{1}{4} \\ 20 & & \\ \hline \end{array}$$

$$\begin{array}{l} 297 \text{ shillings.} \\ 12 \\ \hline 3572 \text{ pence.} \\ 4 \\ \hline \end{array}$$

Answer. 14289 farthings.

Then, 20 shillings = 1 pound ; multiply the pounds, 14, by 20, and add the odd shillings, 17, the result is the shillings. Again, 12 pence = 1 shilling ; multiply the shillings, 297, by 12, and add the odd pence, 8, the result is the pence. Finally, 4 farthings = 1 penny ; multiply the pence, 3572, by 4, and add the odd farthing, 1, the result is the answer.

Example 2.—Reduce 14289 farthings to pounds.

$$\begin{array}{l} 4)14289 \\ \hline 12)3572\ \frac{1}{4} \\ \hline 2,0)29,7\ 8\frac{1}{4} \\ \hline \pounds 14\ 17\ 8\frac{1}{4} \text{ Answer.} \\ \hline \end{array}$$

Divide the farthings by 4, the quotient is the pence with a remainder of 1 farthing, which express as in the quotient. Next, divide the pence by 12, the quotient is the shillings with a remainder of 3 pence. Finally, divide the shillings by 20, the quotient is the pounds with the remainder 17 shillings. Arrange the quotient as in the solution.

EXERCISES.

1 Reduce £14 13s. 7d. to pence. Answer. 3523d.
2 Reduce £97 16s. 9d. to pence. Answer. 23481d.
3 Reduce £351 13s. 0¾d. to farthings. Answer. 337587q.
4 Reduce 3775 sixpences to pounds. Answer. £94 7s. 6d.
5 Reduce 821774 farthings to pounds. Answer. £856 0s. 3½d.
6 Reduce 42147 half-pence to pounds. Answer. £87 16s. 1½d.

AVOIRDUPOIS WEIGHT.

			Abbreviations.
16 drams	=	1 ounce.	oz.
16 ounces	=	1 pound.	lb.
28 pounds	=	1 quarter.	qr.
4 quarters	=	1 hundredweight = 112 lbs.	cwt.
20 hundredweights	=	1 ton = 2240 lbs.	

Example 1.—Reduce 7 tons 4 cwts. 3 qrs. 14 lbs. to lbs.

tons cwts. qrs. lbs.
7 4 3 14
20

144
4

579
28

4646
1158

16226 lbs. Answer.

Example 2.—Reduce 16427 lbs. to tons.

1 ton = 2240)16427(7 tons 6 cwts. 2 qrs. 19 lbs. Answer.
15680

1 cwt. = 112)747(6
672

1 qr. = 28)75(2
56

19

EXERCISES.

		Answers.
1	Reduce 19 tons 0 cwts. 2 qrs. 7 lbs. to lbs.	42623 lbs.
2	Reduce 17 tons 14 cwts. 3 qrs. 21 lbs. to lbs.	39753 ,,
3	Reduce 11 tons 5 cwts. 1 qr. 0 lbs. to lbs.	25228 ,,
4	Reduce 74169 lbs. to tons	33 tons 2 cwts. 0 qrs. 25 lbs.
5	Reduce 21572 lbs. to tons	9 ,, 12 ,, 2 ,, 12 ,,
6	Reduce 18736 lbs. to tons	8 ,, 7 ,, 1 ,, 4 ,,

LONG, OR LINEAL MEASURE.

12 inches = 1 foot.
3 feet = 1 yard.
1760 yards = 1 geographical mile.
5280 feet = 1 mile.
6080 feet = 1 knot ; or nautical mile.

Example 1.—Reduce 19 feet 6 inches to inches.

ft. in.
19 6
12

234 inches. Answer.

Example 2.—Reduce 157 inches to feet.

12)157

ft. 13 1 inch. Answer.

SQUARE, OR SUPERFICIAL MEASURE.

144 square inches = 1 square foot.
9 square feet = 1 square yard.

Example 1.—Reduce 10 square feet 14 square inches to inches.

10
144

1440
14

1454 sq. inches. Answer.

Example 2.—Reduce 1794 square inches to square feet.

144)1794(12 sq. ft. 66 sq. in. Answer.
144
354
288
66

SOLID MEASURE.

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.

Example.—Reduce 52649 cubic inches to cubic feet.

1728)52649(30 ft. 809 in. Answer.
5184
809

Example 2.—Reduce 27 cubic feet 47 cubic inches to inches.

1728
27
12096
3456
47
46703 inches. Answer.

MEASURE OF CAPACITY.

4 gills = 1 pint pt.
2 pints = 1 quart qt.
4 quarts = 1 gallon gal.

Example 1.—Reduce 14 gals. 3 qts. 1 pt. 3 gills to gills.

gal.	qt.	pt.	gill
14	3	1	3
4			
59			
2			
119			
4			
479 gills. Answer.			

Example 2.—Reduce 542 gills to gallons.

4)542

2)135 2

4)67 1 2

16 gal. 3 qt. 1 pt. 2 gill. Answer.

COMPOUND ADDITION.

	£	s.	d.
	52	16	7½
	14	12	0¾
	21	6	7¼
Answer.	88	15	3½

The sum of the column of farthings is 6, divide 6 by the farthings in a penny, that is by 4, the quotient is 1 with a remainder of two farthings, that is ½ a penny, put ½ down. Then, carry 1 to the column of pence; the sum of this column is 15, divide by 12, the pence in 1 shilling, the quotient is one with a remainder of 3 pence, put 3 down. Next, carry 1 to the shillings, the sum is 35, which divide by 20, the quotient is 1 with a remainder of 15, put 15 down. Finally, carry 1 to the pounds, and proceed as in simple addition.

EXERCISES.

	£	s.	d.
(1)	29	14	3½
	17	12	2¼
	8	6	7¾
	55	13	1½

	tons	cwts.	qrs.	lbs.
(2)	42	11	1	14
	17	12	2	19
	27	15	3	27
	88	0	0	4

	d.	h.	min.	sec.
(3)	14	12	32	15
	15	10	17	42
	5	21	6	18
	35	19	56	15

COMPOUND SUBTRACTION.

Example.

	£	s.	d.
From	27	13	4¼
Take	18	14	6¾
Answer	8	18	9½

3 farthings cannot be taken from 1 farthing, *borrow* 4 farthings, which is equal to 1 penny, the sum of 1 and 4 is 5, from which take 3, the remainder is 2, or 2 farthings, which are equal to 1 half-penny, the remainder ; put down ½. Then *carry* 1 penny to the 6 pence, the sum is 7 pence, which cannot be taken from 4 pence, borrow 12 pence, which is equal to 1 shilling, the sum of 4 and 12 is 16, from which take 7, the remainder is 9, put 9 down. Next, carry 1 shilling to the 14 shillings, the sum is 15 shillings, add 20 to 13, the sum is 33, from which take 15, the remainder is 18, put it down. Finally, add 1 pound to the 18 pounds, and proceed as in simple subtraction.

EXERCISES.

(1)	tons	cwts.	qrs.	lbs.	
	240	17	1	21	
	118	18	2	29	
	121	18	2	20	Answer.

(2)	d.	h.	min.	sec.	
	21	14	27	16	
	17	21	32	41	
	3	16	54	35	Answer.

COMPOUND MUTIPLICATION.

Example 1.—Multiply £13 15s. 5¾d. by 5.

£	s.	d.
13	15	5¾
		5
68	17	4¾

Multiply 3 by 5, the product is 15, which divide by 4 the result is 3 and 3 over, put ¾ down. Again, multiply 5 by 5 and add 3, the result is 28, which divide by 12, the result is 2 and 4 over, put 4 down. Again, multiply 15 by 5 and add 2, the result is 77, which divide by 20, the result is 3 and 17 over, put 17 down. Finally, multiply 13 by 5 and add 3, the result is 68, which put down.

Example 2.—Multiply £17 14s. 2½d. by 34.

34 = 8 × 4 + 2

£	s.	d.	
17	14	2½	× 2
		8	
141	13	8	
		4	
566	14	8	
35	8	5	
602	3	1	Answer.

Example 3.—Multiply £12 11s. 10¼d. by 6347.

6347 = 6000 × 300 × 40 × 7
6000 = 10 × 10 × 10 × 6
300 = 10 × 10 × 3
40 = 10 × 4

£	s.	d.	
12	11	10¼	× 7
		10	
125	18	6½	× 4
		10	
1259	5	5	× 3
		10	
12592	14	2	
		6	
75556	5	0	
3777	16	3	
503	14	2	
88	2	11¾	
79925	18	4¾	

EXERCISES.

				£	s.	d.
1	Multiply	£0 8s. 11d. by 101	Answer.	45	0	7
2	,,	£0 11s. 11½d. by 114	,,	68	3	3
3	,,	£31 7s. 6½d. by 138	,,	4330	0	9
4	,,	17 tons 14 cwt. 2 qrs. 19 lbs. by 6	,,	106 tons 8 cwt. 0 qr. 2 lbs.		
5	,,	10 cwt. 2 qrs. 17 lbs. by 18	,,	9 tons 11 cwt. 2 qr. 26 lbs.		
6	,,	7 gals. 0 qt. 1 pt. by 47	,,	334 gals. 3 qts. 1 pt.		

COMPOUND DIVISION.

SHORT DIVISION.

Example 1.—Divide £42 17s. 4½d. by 8.

```
   £  s.  d.
8)42 17  4½
  ─────────
   5  7  2 1/16  Answer.
```

Divide 42 by 8, the quotient is 5 with a remainder 2, put down 5. Again, multiply 20 by 2 and add 17, the result is 57, which divide by 8, the quotient is 7 with a remainder 1, put down 7. Again, multiply 12 by 1 and add 4, the result is 16, which divide by 8, the quotient is 2, put it down. Finally, multiply the lower figure of ½ by 8 and put down $\frac{1}{16}$.

LONG DIVISION.

Example 2.—Divide £729 16s. 4¾d. by 101.

```
       £   s.  d.  £  s. d. qr.
   101)729 16  4¾(7  4  6 91/101  Answer.
       707
       ───
        22
        20
       ───
   101)456(4
       404
       ───
        52
        12
       ───
    101)628(6
        606
        ───
         22
          4
        ───
        91/101
```

729 contains 101, 7 times, with a remainder 22, put 7 down. Again, multiply 22 by 20 and add 16, the result is 456, which contains 101, 4 times, with a remainder 52, put 4 down. Again, multiply 52 by 12 and add 4, the result is 628, which contains 101, 6 times, with a remainder 22, put 6 down. Finally, multiply 22 by 4 and add 3, the result is 91, which is less than 101, draw a line under the 91 and put 101 under the line.

EXERCISES.

		£ s. d.		£ s. d.
1	Divide	6 10 7½ by 19	Answers.	0 6 10½
2	Divide	43 14 10 by 29		1 10 2
3	Divide	38 10 6 by 67		0 11 6
4	Divide	5 cwt. 1 qr. 27 lbs by 3		1 cwt. 3 qrs. 9 lbs.
5	Divide	21 tons 12 cwt. 2 qrs. by 5		4 tons 6 cwt. 2 qrs.
6	Divide	749 gals. 2 qts. 1 pt. 2 gills by 10		74 gals. 3 qts. 1 pt. 3 gills.

VULGAR FRACTIONS.

A *Vulgar Fraction* is one or more parts of a whole number, and it is expressed by a number above a line and another below it ; thus $\frac{2}{3}$. The number below the line is called the *denominator*, and that above is called the *numerator*. The denominator shews how many parts the whole number is divided into, and the numerator shews how many of those parts are taken. A *proper fraction* has its numerator less than its denominator. An *improper fraction* has its numerator equal to, or greater than its denominator.

REDUCTION OF FRACTIONS.

TO REDUCE FRACTIONS TO LESS TERMS.

Example.—Reduce $\frac{240}{360}$ to less terms.

Divide both terms of the fraction to any number that will divide them without a remainder ; as follows :—

$$\frac{240}{360} = \frac{24}{36} = \frac{4}{6} = \frac{2}{3} \text{ Answer.}$$

Here 10 will divide both 240 and 360 without a remainder ; 6 will divide 24 and 36 ; and 2 will divide 4 and 6 ; but there is no number except 1 that will divide 2 and 3. In this case $\frac{2}{3}$ are the least terms of the fraction $\frac{240}{360}$.

TO REDUCE FRACTIONS TO A COMMON DENOMINATOR.

Example.—Reduce $\frac{7}{9}$ and $\frac{3}{4}$ to a common denominator.

$$\frac{7}{9} \text{ and } \frac{3}{4} = \frac{28}{36} \text{ and } \frac{27}{36}.$$

Multiply each of the terms of the fraction $\frac{7}{9}$ by 4 and they become $\frac{28}{36}$. Again, multiply each of the terms of the fraction $\frac{3}{4}$ by 9 and they become $\frac{27}{36}$.

IMPROPER FRACTIONS.

Example 1.—Reduce $\frac{74}{19}$ to a mixed number.

$$\begin{array}{l} 19)74(3\frac{17}{19} \text{ Answer.} \\ \quad\;\; 57 \\ \quad\;\; \overline{17} \\ \quad\;\; \overline{} \end{array}$$

Divide 74 by 19, the quotient is 3 with a remainder 17 ; draw a line under 17 and put 19 under the line, as in the solution.

EXERCISES.

No.				Answers.
1	Reduce	$\frac{187}{27}$	to a mixed number	$6\frac{25}{27}$
2	,,	$\frac{24}{3}$	,,	8
3	,,	$\frac{1748}{17}$	,,	$102\frac{14}{17}$
4	,,	$\frac{65}{5}$	,,	13
5	,,	$\frac{178}{9}$	,,	$19\frac{7}{9}$
6	,,	$\frac{72}{6}$	,,	12

Example 2.—Reduce the mixed number $4\frac{6}{9}$ to a simple fraction.

$$\begin{array}{r} 4\frac{6}{9} \\ 9 \\ \hline 42 \\ \hline \end{array} \qquad \frac{42}{9} \text{ Answer.}$$

Multiply 4 by 9 and add 6, the result is 42, draw a line under 42 and put 9 under the line.

Example 3.—Reduce the whole number 6 to the form of a vulgar fraction.

$\frac{6}{1}$ Answer.

Draw a line under 6 and put 1 under the line.

EXERCISES.

No.				Answers.
1	Reduce	$6\frac{1}{4}$	to a simple fraction	$\frac{25}{4}$
2	,,	7	,,	$\frac{7}{1}$
3	,,	$17\frac{3}{4}$	,,	$\frac{71}{4}$
4	,,	$174\frac{3}{18}$	,,	$\frac{3135}{18}$
5	,,	$16\frac{4}{19}$	,,	$\frac{308}{19}$
6	,,	$319\frac{16}{26}$	,,	$\frac{8310}{26}$

ADDITION OF VULGAR FRACTIONS.

Example 1.—Add $\frac{1}{9}$, $\frac{7}{9}$ and $\frac{8}{9}$ together.

$$\begin{array}{r} 1 \\ 7 \\ 8 \\ \hline 16 \\ \hline \end{array} \qquad \text{Sum} = \frac{16}{9} = 1\frac{7}{9} \text{ Answer.}$$

The fractions have the common denominator 9, add the numerators together, their sum is 16, draw a line under the 16 and put 9 under the line ; divide 16 by 9 the quotient is 1, with a remainder 7, put 7 down, draw a line under it, and put 9 under the line.

Example 2.—Find the sum of $\frac{3}{4}$, $\frac{5}{6}$ and $\frac{7}{8}$.

Reduce the fractions to their least common denominator 24, by dividing 24 by 4, 6, and 8, respectively; the quotients are 6, 4, and 3, respectively. Multiply the terms of the first fraction by 6, those of the second by 4, and those of the third by 3; the resulting fractions are $\frac{18}{24}$, $\frac{20}{24}$ and $\frac{21}{24}$; and their sum is $\frac{59}{24} = 2\frac{11}{24}$. Answer.

EXERCISES.

No.	Add.	Answers.
1	$\frac{3}{7}, \frac{4}{7}, \frac{6}{7}$	$\frac{13}{7} = 1\frac{6}{7}$
2	$\frac{4}{7}. \frac{3}{4}, \frac{1}{6}, \frac{4}{9}$	$\frac{487}{252} = 1\frac{235}{252}$
3	$\frac{1}{2}, \frac{2}{3}, 5$	$\frac{37}{6} = 6\frac{1}{6}$
4	$6\frac{1}{7}, \frac{1}{4}, \frac{1}{2}$	$\frac{193}{28} = 6\frac{25}{28}$

SUBTRACTION OF VULGAR FRACTIONS.

Example 1.—Find the difference between $\frac{8}{9}$ and $\frac{1}{9}$. Answer $\frac{7}{9}$.

$$\begin{array}{c} 8 \\ 1 \\ \hline 7 \\ \hline \end{array}$$

The fractions have the common denominator 9, 1 taken from 8 leaves 7, put 7 down, draw a line under it, and put 9 below the line.

Example 2.—Find the difference between $\frac{8}{9}$ and $\frac{4}{7}$.

Reduce the fractions to equivalent fractions, having the least common denominator 63, by multiplying the terms of the first fraction by 7, and those of the second by 9, the resulting fractions are $\frac{56}{63}$ and $\frac{36}{63}$, take 36 from 56 the remainder is 20, draw a line under 20, and put 63 under the line; the answer is $\frac{20}{63}$,

EXERCISES.

				Answers.
1.	$\frac{9}{10}$	—	$\frac{2}{5}$	$\frac{1}{2}$
2.	$\frac{3}{4}$	—	$\frac{1}{2}$	$\frac{1}{4}$
3.	$\frac{7}{16}$	—	$\frac{1}{8}$	$\frac{5}{16}$
4.	$\frac{13}{16}$	—	$\frac{1}{4}$	$\frac{9}{16}$
5.	$\frac{7}{8}$	—	$\frac{1}{3}$	$\frac{13}{24}$
6.	$\frac{7}{16}$	—	$\frac{1}{5}$	$\frac{19}{80}$

MULTIPLICATION OF VULGAR FRACTIONS.

Example.

$$\frac{\overset{1}{3}}{4} \times \frac{5}{\underset{2}{6}} = \frac{1 \times 5}{4 \times 2} = \frac{5}{8}$$

The number 3 will divide both the numerator 3 and the denominator 6, without a remainder, the quotients are respectively 1 and 2. Arrange the solution as in the example, and the answer is $\frac{5}{8}$. Or, multiply the numerators, 3 and 5, together, and the denominators, 4 and 6, together, the resulting fraction is $\frac{15}{24}$, which, when reduced to its least terms, becomes $\frac{5}{8}$.

EXERCISES.

		Answers.
1	$\frac{7}{8}\times\frac{3}{4}\times\frac{8}{9}$	$\frac{7}{12}$
2	$\frac{3}{4}\times\frac{5}{8}$	$\frac{15}{32}$
3	$\frac{7}{9}\times\frac{8}{11}$	$\frac{56}{99}$
4	$\frac{9}{11}\times\frac{4}{12}$	$\frac{3}{11}$
5	$\frac{4}{13}\times\frac{4}{27}$	$\frac{16}{351}$
6	$\frac{1}{2}\times\frac{2}{3}\times\frac{3}{4}\times\frac{5}{6}\times\frac{6}{7}\times\frac{7}{8}\times\frac{8}{9}\times\frac{9}{10}$	$\frac{1}{10}$

DIVISION OF VULGAR FRACTIONS.

Example.—$\frac{2}{3}\div\frac{3}{4} = \frac{2}{3}\times\frac{4}{3} = \frac{8}{9}$ Answer.

Invert the divisor $\frac{3}{4}$ and it becomes $\frac{4}{3}$, then multiply $\frac{2}{3}$ by $\frac{4}{3}$.

EXERCISES.

		Answers.
1	$\frac{4}{7}\div\frac{3}{5}$	$\frac{20}{21}$
2	$\frac{14}{5}\div\frac{11}{12}$	$3\frac{3}{55}$
3	$\frac{15}{16}\div\frac{4}{5}$	$1\frac{11}{64}$
4	$\frac{33}{35}\div\frac{3}{8}$	$2\frac{18}{35}$
5	$\frac{12}{37}\div\frac{18}{43}$	$\frac{86}{111}$
6	$\frac{16}{351}\div\frac{4}{27}$	$\frac{108}{351}$

TO REDUCE QUANTITIES OF ONE KIND TO THE FRACTION OF ANOTHER KIND.

Example.—Reduce 11s. 2¾d. to the fraction of a pound.

s.	d.	£	s.	d.	
11	2¾	1	0	0	£$\frac{539}{960}$ Answer.
12		20			
134		20			
4		12			
539		240			
		4			
		960			

Farthings is the lowest denomination in the first quantity, reduce both quantities to farthings, and take the first as the numerator and the second as the denominator of the required fraction.

EXERCISES.

No.		s. d.			Answers.
1	Reduce	17 4	to the fraction of	£1	£$\frac{13}{15}$
2	„	4 7½	„	„	£$\frac{37}{160}$
3	„	0 9½	„	a shilling	$\frac{18}{24}$
4	„	2 qrs. 14 lbs.	„	cwt.	$\frac{5}{8}$ cwt.
5	„	2 qrs. 13 lbs.	„	cwt.	$\frac{69}{112}$ cwt.
6	„	3 qrs. 17¾ lbs.	„	cwt.	$\frac{407}{408}$ cwt.

TO FIND THE VALUE OF SIMPLE FRACTIONS.

Example.—Find the value of £$\frac{7}{8}$.

By long division.

```
    7 £
    20
8)140(17s. 6d.  Answer.
   8
   —
   60
   56
   —
    4
   12
   —
 8)48(6
   48
```

By short division.

```
8)7
———
17s. 6d.  Answer.
———
```

Long division. Multiply 7 by 20, the product is 140, which divide by 8, the quotient is 17 with a remainder 4. Multiply 4 by 12 the product is 48, which contains 8, 6 times ; hence the answer is 17s. 6d. Short division. Go through the preceding process mentally.

EXERCISES.

No.			Answers.
1	Find the value	£ $\frac{2}{3}$	13s. 4d.
2	„	$\frac{3}{4}$ s.	0s. 9d.
3	„	£ $\frac{6}{7}$	17s. 1½d. $\frac{6}{7}$ qr.
4	„	$\frac{9}{11}$ day	19 h. 38 m. 10$\frac{10}{11}$s.
5	„	$\frac{23}{27}$ cwt.	3 qrs. 11$\frac{11}{27}$ lbs.
6	„	$\frac{3}{7}$ hour	25 m. 42$\frac{6}{7}$s.

COMPLEX FRACTIONS.

Example 1.—Reduce $\frac{\frac{1}{4}}{7}$ to a simple fraction.

$$\frac{\frac{1}{4}}{7} = \frac{\frac{1}{4}}{\frac{7}{1}} = \frac{1}{4}\times\frac{1}{7} = \frac{1}{28} \text{ Answer.}$$

Example 2.—Reduce $\frac{3}{10\frac{1}{4}}$ to a simple fraction.

$$\frac{3}{10\frac{1}{4}} = \frac{3}{\frac{41}{4}} = \frac{3\times4}{41} = \tfrac{12}{41} \text{ Answer.}$$

Example 3.—Reduce $\frac{2\frac{1}{3}}{4\frac{3}{4}}$ to a simple fraction.

$$\frac{2\frac{1}{3}}{4\frac{3}{4}} = \frac{\frac{7}{3}}{\frac{19}{4}} = \frac{7}{3}\times\frac{4}{19} = \tfrac{28}{57} \text{ Answer.}$$

Reduce the terms of the complex fraction to the form of the simple fractions, then multiply the numerator of the complex fraction by its denominator inverted.

EXERCISES.

No.				Answers.
1	Reduce	$\frac{3\frac{1}{2}}{4\frac{1}{5}}$	to a simple fraction	$\frac{5}{6}$
2	,,	$\frac{4}{11\frac{3}{11}}$	,,	$\frac{11}{31}$
3	,,	$\frac{13\frac{7}{8}}{19}$	,,	$\frac{111}{152}$
4	,,	$\frac{74\frac{1}{9}}{\frac{7}{8}}$	,,	$\frac{5336}{63}$
5	,,	$\frac{\frac{9}{11}}{83\frac{1}{3}}$	,,	$\frac{27}{2750}$
6	,,	$\frac{6\frac{1}{7}}{14\frac{4}{9}}$	,,	$\frac{387}{910}$

DECIMAL FRACTIONS.

Decimal Fractions, or shortly *Decimals*, are fractions in which the numerator alone is expressed, the denominator being understood to be always 1 with as many ciphers annexed as there are figures, either ciphers or integers, in the numerator.

NOTATION OF DECIMALS.

Decimals are distinguished from whole numbers by a point to the left of them; thus ·5 is the decimal notation for $\frac{5}{10}$, ·04 for $\frac{4}{100}$, and 64·72 for $64\frac{72}{100}$.

ADDITION OF DECIMALS.

RULES.

1. Place the decimal points in a line one above another, and the whole numbers and decimals in order, as in the examples, then proceed as in addition of whole numbers.

2. Place the decimal point in the sum exactly below the others.

Example 1.—Add 2·04, 7·253, and 6.9 together.

2·04
7·253
6·9

Answer 16·193

Example 2.—Add ·0007, 246·5, 42·82 together.

·0007
246·5
42·32

Answer 288·8207

SUBTRACTION OF DECIMALS.

RULE.

Place the lesser number under the greater, set the decimal points as in addition of decimals, then subtract as in whole numbers and place the decimal point in the remainder exactly under the others.

Example 1.—Subtract 7·06 from 12·22.

12·22
7·06

Answer 5·16

Example 2.—Subtract ·005 from 18·042.

18·042
·005

Answer 18·037

MULTIPLICATION OF DECIMALS.

RULES.

1.—Multiply as in whole numbers.

2.—To place the decimal point, count from the right hand of the product as many figures as there are places of decimals in both multiplicand and multiplier. If there be not as many figures in the product, supply the defect by ciphers on the left hand.

Example 1.—Multiply 7·42 by 3·19.

7·42
3·19

6678
742
2226

23·6698 Answer.

Example 2.—Multiply ·07 by ·003.

·07
·003

·00021 Answer.

DIVISION OF DECIMALS.

RULE.

Divide as in whole numbers; and to place the decimal point, consider that the number of decimals in the dividend must always be equal to the number of those in both divisor and quotient added together.

Example 1.—Divide ·763 by 74·2.

74·2)·763(·010283 Answer.
742

2100
1484

6160
5936

2240
2226

14

The whole number 763 contains the whole number 742, 1 time, with a remainder 21; now there are 3 decimals in ·763 but only 1 in 74·2, prefix a decimal point and a cipher to the 1 in the quotient, then there will be 3 decimals in the divisor and quotient together, which is the number of decimals in the dividend.

Example 2.—Divide 216 by ·000074.

```
·000074)216·000000(2918918·918
        148
        ---
         680
         666
         ---
          140
           74
          ---
           660
           592
           ---
            680
            666
            ---
             140
              74
             ---
              660
              592
              ---
               680
               666
               ---
                140
                 74
                ---
                 660
                 592
                 ---
                  68
                 ---
```

Place a decimal point after 216, and affix 6 ciphers, then divide till all the ciphers are exhausted, place a decimal point after the quotient and proceed, as in the solution, to as many decimal places in the quotient as may be required.

No.		EXERCISES.			Answers.
1	Divide	6·74	By	2·34	2·8803+
2	”	·496	”	·278	1·784 +
3	”	7·6	”	·734	10·354+
4	”	7·23	”	4·06	1·7807+
5	”	·024	”	·001	24
6	”	29·6	”	10	2·96

+ After an answer denotes that the quotient may be carried to a greater number of decimal places.

TO REDUCE A VULGAR FRACTION TO A DECIMAL.

Example.—Reduce $\frac{7}{8}$ to a decimal.

$$\frac{7{\cdot}0}{8} = {\cdot}875 \text{ Answer.}$$

Place a decimal point after the 7, and affix a cipher, then divide the 70 by 8, the quotient is 8 with a remainder 6; place a decimal point before the 8.

Next, affix a cipher, mentally, to the 6 and divide as before. Proceed thus as far as may be necessary.

EXERCISES.

Reduce $\frac{1}{8}$; $\frac{3}{8}$; $\frac{5}{8}$; $\frac{1}{4}$; $\frac{3}{4}$; $\frac{1}{16}$; $\frac{3}{16}$; $\frac{5}{16}$; $\frac{7}{16}$; $\frac{9}{16}$; $\frac{11}{16}$; $\frac{13}{16}$ and $\frac{15}{16}$ respectively to a decimal.

Answers ·125; ·375; ·625; ·25; ·75; ·0625; ·1875; 3125; ·4375; ·5625; ·6875; ·8125; ·9375.

Note.—16 = 4×4; hence when dividing 16 it is convenient to divide by 4 and by 4 again.

TO FIND THE VALUE OF A FRACTION.

Example 1.—Find the value of £·75.

·75 £
20 s. = £1

15·00 s. Answer 15s.

Example 2.—Find the value of 4·74909 tons.

4·74909 tons
20 cwts = 1 ton

14·98180 cwts
4 qrs = 1 cwt

3·9272 lbs
28 lbs = 1 qr

74176
18544

25·9616 lbs.

Answer 4 tons 14 cwts 3 qrs 25·9616 lbs.

PROPORTION.

The *Ratio* of two quantities is the number of times that one contains the other; thus 6 contains 2, 3 times; hence 3 is the ratio of 6 to 2; and it is expressed thus $6 : 2 = 3$; or thus $\frac{6}{2} = 3$.

A *Proportion* consists of two equal ratios. Thus $6 : 2 = 3$, and $18 : 6 = 3$, are two equal ratios; and expressed as follows they form a proportion.

$$6 : 2 :: 18 : 6 \text{ or } \frac{6}{2} = \frac{18}{6}$$

The first form is read—As 6 is to 2 so is 18 to 6.

Example 1.—If 7 cwts cost £21, how much will 5 cwts cost?

$$\begin{array}{ccccr}
\text{cwts.} & & \text{cwts.} & & \pounds \\
7 & : & 5 & :: & 21 \\
 & & & & 5 \\ \cline{5-5}
 & & & & 7)105 \\ \cline{5-5}
 & & & & \pounds 15 \text{ Answer.}
\end{array}$$

Example 2.—If 13 yards cost 16s. what is the cost of 39 yards?

$$\begin{array}{ccrcc}
\text{yds.} & & \text{yds.} & & \text{s.} \\
13 & : & 39 & :: & 16 \\
 & & 16 & & \\ \cline{3-3}
 & & 234 & & \\
 & & 39 & & \\ \cline{3-3}
 & & 13)624(48\text{s.} & & \text{Answer.} \\
 & & 52 & & \\ \cline{3-3}
 & & 104 & & \\
 & & 104 & & \\ \cline{3-3}
\end{array}$$

In the first example two of the given quantities are of the same kind; namely cwts., and these must be the first and second terms of the proportion. Now 7 cwts. will cost more than 5 cwts., put 7 the first term, 5 the second, and the remaining quantity £21 the third. Multiply the second and the third terms together, and divide by the first, the quotient is the answer, and it is of the same name as the third term. In the second example 13 yards will cost less than 39 yards, and therefore 13 must be put the first term, 39 the second, and 16 the third.

EXERCISES.

1. A person spends £2 16s. 8d. per week; how much is that per annum? Answer £147 6s. 8d.

2. If 24 yards costs £3 14s. 7d. ; how much is that per yard ? Answer 3s. 1d. $\frac{1}{4}$ + $\frac{1}{6}$.

3. A ship was provisioned for a crew of 40 men for 3 months ; how long would these provisions last if the crew were reduced to 32 men ? Answer 3$\frac{3}{4}$ months.

4. How much silver will £85 1s. buy at 5s. 2d. per ounce ? *Note* : 12 oz. = 1 lb. Answer 27 lb.

5. If 42 men can perform a piece of work in 36 days, how many men will it take to finish it in 6 days ? Answer 252 men.

6. How many cwts. of beef may be bought for £42 10s., when 14 lbs. cost 7s. 1d. ? Answer 15 cwts.

COMPOUND PROPORTION.

Example 1.—If 14 horses eat 56 bushels of oats in 16 days ; how many bushels will be required for 20 horses for 24 days ?

14 horses : 20 horses : : 56 bushels.
16 days : 24 days : :

84 480
14 56

224 2880
2400

224)26880(120 bushels. Answer.
224

448
448

0

Form two proportions as follows : in both proportions bushels are wanted, hence 56 must be the third term. Again, in the first proportion, 20 horses will, in the same time, eat more oats than 14 horses will ; hence 20 must be the second term, and 14 the first. Again, in the second proportion, more oats will be eaten in 24 days than there will in 16 days ; hence 24 must be the second term, and 16 the first. Then proceed as in the solution.

Note.—By proceeding as in proportion the answer to the first of the two preceding proportions will be 80 bushels, and by making 80 the third term in the second proportion, the answer will be 120 bushels, the same as above.

EXERCISES.

1. If 454 tons of Welsh coal in the bunkers be sufficient for a voyage cf 2900 miles, and Lancashire coal be for space in the proportion of 46 to 40, and inferior in quality as 8·7 to 10·7 ; what distance will the bunkers carry her if filled with Lancashire coal ? 2050·89 miles. Answer.

2. If 100 make 8 miles of road in 27 days ; in how many days will 150 men make 5 miles ? 30 days. Answer.

PRACTICE.

Example.—173 at 2s. 6¾d.

2	$\frac{1}{10}$	173			
6	¼	17	6	0	
½	$\frac{1}{12}$	4	6	6	
¼	½		7	2½	
			3	7¼	
		£22	3	3¾	Answer.

2s. = $\frac{1}{10}$ of £1 ; 6d. = ¼ of 2s. ; ½d. = $\frac{1}{12}$ of 6d. ; and ¼q. = ½ of ½d. Arrange as in the solution, divide by short division, and add the several quotients.

EXERCISES.

No.			s.	d.		£	s.	d.
1	614	at	1	8	Answer	51	3	4
2	166	,,	6	8	,,	55	6	8
3	872	,,	0	1½	,,	5	9	0
4	714	,,	0	0¼	,,	0	14	10½
5	292	,,	1	1¼	,,	16	2	5
6	671	,,	1	8¾	,,	58	0	3¼

INTEREST, DISCOUNT.

Example 1.—What is the simple interest of £214 15s. 6d. at 5 per cent. per annum ?

£		£		£	s.	d.		£	s.	d.
100	:	5	: :	214	15	6	Answer	10	14	9·3
						5				

1,00)10,73 17 6

10·73
20

14·77
12

9·30

Example 2.—What is the discount on a bill of £142 15s. 10d. at 7½ per cent.

£ s. d.
2)142 15 10
7½

999 10 10
71 7 11

1,00)10,70 18 9

10·70 Answer £10 14s. 2·25d.
20

14·18
12

2·25

INVOLUTION.

Example 1. 9^2

9
9

81 Answer.

Example 2. 4^3

4
4

16
4

64 Answer.

Example 3. 5^4

5
5

25
5

125
5

625 Answer.

EVOLUTION.

SQUARE ROOT.

Example 1. √ 256.

· ·
256(16 Answer.
1

26)156
156

Example 2. √ 297·5625.

· · ·
297·5625(17·25 Answer.
1

27)197
189

342)856
684

3445)17225
17125

In the 2nd example ; begin at the decimal point and point off two figures each way. The square of 1 is 1 which is not greater than the first one or two figures as the case may be ; in this question it is not greater than 2 ; put 1 down for the first figure in the square root, and its square under 2, as in the solution. Subtract 1 from 2, and to the remainder 1 annex the two figures 97, the sum is 197: to find the divisor, double the quotient figure 1, the sum is 2, to 2 annex 7, multiply 27 by 7, the product is 189 which is less than 197. Again, subtract 189 from 197 and to the remainder 8, bring down the next two figures, 56, add the last quotient figure 7 to the divisor 27, the sum is 34, to which annex 2, and the new divisor becomes 342 ; multiply 342 by 2 and the product is 684. Again, subtract 684 from 856, the remainder is 172, to which bring down the next two figures 25, add the last quotient figure 2 to the divisor 342, the sum is 344 to which annex 5, and the new divisor becomes 3445 ; multiply 3445 by 5. Thus the square root of the given number is found to be 17·25.

Example 3.—Find the square root of 4111·3744.

· · · ·
4111·3744(64.12 Answer.
36

124)511
496

1281)1537
1281

12822)25644
25644

The square of 7 is 49, which is greater than the first two figures 41 ; but the square of 6 is 36, which is less than 41.

EXERCISES.

No.			Answer.
1	Find the square root of	7590·417129	87·123
2	„	67897·0186	260·57+
3	„	12345·729	111·11+
4	„	718·6721$\dot{3}$	26·80806+
5	„	5078·2$\dot{3}$	71·2617+
6	„	12·	3·464+

Note.—+ After an answer denotes that the answer may be carried farther by annexing ciphers. Questions 4th and 5th have a point above the last figure ; in case it be necessary to carry the answer farther repeat the last figure as often as may be required.

EXTRACTION OF THE CUBE ROOT.

Example 1.—Extract the cube root of 76765·625.

```
          .    .
         76765·525(42·5  Answer.
         64
         ------
    5044)12765
         10088
         --------
  535525)2677625
          2677625
          --------
```

TO FIND THE FIRST FIGURE IN THE ANSWER.

```
 4
 4
 --
16
 4
 --
64
 --
```

TO FIND THE FIRST DIVISOR.

```
   4        4      2
   4        2      2
  --       --     --
  16        8      4
  300      30     --
  ----    ----
  4800     240
   240    ----
     4
  ----
  5044
  ----
```

TO FIND THE SECOND DIVISOR.

```
     42           42          5
     42            5          5
     --          ---         --
     84          210         25
    168           30         --
    ---          ----
   1764          6300
     300         ----
 ------
 529200
   6300
     25
 ------
 535525
 ------
```

EXERCISES.

Extract the cube root of—

No.			Answers.
1	11089567	....	223
2	4149·995543	....	16·07
3	800125·725	....	92·8+
4	401719179·	....	737·+
5	122615327232	....	4968
6	27407028375	....	3015

PART II.

EXAMINATIONS OF ENGINEERS

FOR CERTIFICATES OF COMPETENCY,

Under the Merchant Shipping Acts Amendment Act, 1862.

1. Applicants for examination must give their names to the Local Marine Board, if the place where they intend to be examined is a port where there is a Local Marine Board, on or before the day of examination (except in the case of London* and Liverpool), and must conform to any regulations in this respect which may be laid down by the Local Marine Board; and if this be not done, delay may be occasioned.

2. Testimonials of character, and of sobriety, experience, ability, and good conduct on board ship will be required of all applicants, and without producing them no person will be examined. As such testimonials may have to be forwarded to the office of the Registrar-General of Seamen in London for verification before any certificates can be granted, it is desirable that candidates should lodge them as early as possible. The testimonials of servitude of Foreigners and of British Seamen serving in foreign vessels, which cannot be verified by the Registrar-General of Seamen, must be confirmed either by the Consul of the country to which the ship in which the candidates served belonged, or by some other recognised official authority of that country, or by the testimony of some credible person on the spot having personal knowledge of the facts required to be established. Upon application to the Superintendent of the Mercantile Marine Office, candidates will be supplied with a form, which they will be required to fill up and lodge with their testimonials in the hands of the Examiners.

3. The examinations will commence early in the forenoon on the days mentioned in the Table appended hereto, and will be continued from day to day until all the candidates whose names appear upon the Superintendent's list on the day of examination are examined.

---

*At London, on Fridays from 10 till 4; and Saturdays from 10 till 3. At Liverpool, on Tuesdays, Wednesdays, Thurdsays, and Saturdays during Office hours.

QUALIFICATIONS FOR CERTIFICATES OF COMPETENCY.

4. SECOND-CLASS ENGINEER.—A candidate for a Second-class Engineer's Certificate must be 21 years of age.

(*a.*) He must have served an apprenticeship to an Engineer, or prove that for not less than three years he has been employed in some factory or workshop on the making or repairing of engines; and must also have *actually served* one year at sea in the Engine Room; or

(*b.*) He must have served at least four years at sea in the Engine Room.

(*c.*) He must be able to give a description of boilers, and the methods of staying them, together with the use and management of the different valves, cocks, pipes, and connections.

(*d.*) He must understand how to correct defects from accident, decay, &c., and the means of repairing such defects.

(*e.*) He must understand the use of the barometer, thermometer, hydrometer, and salinometer.

(*f.*) He must state the causes, effects, and usual remedies for incrustation and corrosion.

(*g.*) He must be able to state how a temporary or permanent repair could be effected in case of derangement of a part of the machinery, or total break down.

(*h.*) He must write a legible hand, and understand the first five rules of arithmetic, and decimals.

(*i.*) He must be able to pass a creditable examination as to the various constructions of paddle and screw engines in general use; as to the details of the different working parts, external and internal, with the use of each part.

5. FIRST-CLASS ENGINEER.—A candidate for a First-class Engineer's Certificate must be 22 years of age.

In addition to the qualifications required for a Second-class Engineer,

(*a.*) He must either possess, or be entitled to a First-class Engineer's Certificate of Service; or in the event of his not being so possessed or entitled, he must have *actually served* for one year with a Second-class Engineer's Certificate of Competency.

(*b.*) He must be able to make rough working drawings of the different parts of the engines and boilers.

(*c.*) He must also be able to take off and calculate indicator diagrams.

(*d.*) He must be able to calculate safety valve pressures, and the strength of the boiler.

(*e.*) He must be able to state the general proportions borne by the principal parts of the machinery to each other.

(*f*.) He must be able to explain the method of testing and altering the setting of the slide valves, and of testing the fairness of the paddle and screw shafts and of adjusting them.

(*g*.) He must be conversant with surface condensation, superheating, and the working of steam expansively.

(*h*.) His knowledge of arithmetic must include the mensuration of superficies and solids, and the extraction of the square root.

6. An Extra First-class Engineer's Examination is voluntary, and is intended for such persons as wish to prove their superior qualifications, and are desirous of having Certificates for the highest grade granted by the Board of Trade.

The Candidate must be entitled to or possessed of a First-class Engineer's Certificate of Competency, and in addition to the qualifications required for a First-Class Engineer,

(*a*.) He must possess a thorough knowledge of the construction and working of marine engines and boilers in all their parts, and be so far acquainted with the elements of theoretical mechanics as to comprehend the general principles on which the machine works.

(*b*.) He must understand how to apply the indicator and draw the proper conclusions from the diagrams.

(*c*.) He must be acquainted with the principles of expansion, and able to prove, or at least to illustrate, the use of the expansion gear.

(*d*.) He must be able to draw rough sketches of any part of the machinery, with figured dimensions fit to work from.

GENERAL RULES AS TO EXAMINATIONS AND FEES.

7. The examinations will be partly *vivâ voce*, and partly by examination papers. They will be directed specially to the above points, and to the duties and business of an Engineer generally.

If the candidate passes the *vivâ voce* examinations creditably, a set of questions will be given to work out.

He will be allowed to work out these questions according to the methods he is accustomed to use, and will be allowed five hours to perform the work: and

(*a*.) If at the expiration of the time allowed he has worked out correctly the whole of the questions set him, he will be declared to have passed.

(*b*.) If at the expiration of the time allowed he has not worked out the whole of the questions set him, but if the result of the vivâ voce examination taken in connection with the answers to such of the questions as he has worked out are sufficient to satisfy the Examiner that the applicant is competent to take charge of engines of 100 nominal horse power or upwards, he will be declared to have passed.

EXERCISES.

1. If 454 tons of Welsh coal in the bunkers be sufficient for a voyage cf 2900 miles, and Lancashire coal be for space in the proportion of 46 to 40, and inferior in quality as 8·7 to 10·7 ; what distance will the bunkers carry her if filled with Lancashire coal ? 2050·39 miles. Answer.

2. If 100 make 8 miles of road in 27 days ; in how many days will 150 men make 5 miles ? 30 days. Answer.

PRACTICE.

Example.—173 at 2s. 6¾d.

2	$\frac{1}{10}$	173		
6	¼	17	6	0
½	$\frac{1}{12}$	4	6	6
¼	½		7	2½
			3	7¼
		£22	3	3¾ Answer.

2s. = $\frac{1}{10}$ of £1 ; 6d. = ¼ of 2s. ; ½d. = $\frac{1}{12}$ of 6d. ; and ¼q. = ½ of ½d. Arrange as in the solution, divide by short division, and add the several quotients.

EXERCISES.

No.			s.	d.		£	s.	d.
1	614	at	1	8	Answer	51	3	4
2	166	,,	6	8	,,	55	6	8
3	872	,,	0	1½	,,	5	9	0
4	714	,,	0	0¼	,,	0	14	10½
5	292	,,	1	1¼	,,	16	2	5
6	671	,,	1	8¾	,,	58	0	3¼

INTEREST, DISCOUNT.

Example 1.—What is the simple interest of £214 15s. 6d. at 5 per cent. per annum ?

£		£		£	s.	d.		£	s.	d.
100	:	5	: :	214	15	6	Answer	10	14	9·3
						5				
			1,00)	10,73	17	6				

10·73
20

14·77
12

9·30

Example 2.—What is the discount on a bill of £142 15s. 10d. at 7½ per cent.

£ s. d.
2)142 15 10
7½

999 10 10
71 7 11

1,00)10,70 18 9

10·70 Answer £10 14s. 2·25d.
20

14·18
12

2·25

INVOLUTION.

Example 1. 9^2

9
9

81 Answer.

Example 2. 4^3

4
4

16
4

64 Answer.

Example 3. 5^4

5
5

25
5

125
5

625 Answer.

EXERCISES.

1. If 454 tons of Welsh coal in the bunkers be sufficient for a voyage cf 2900 miles, and Lancashire coal be for space in the proportion of 46 to 40, and inferior in quality as 8·7 to 10·7 ; what distance will the bunkers carry her if filled with Lancashire coal ? 2050·39 miles. Answer.

2. If 100 make 3 miles of road in 27 days ; in how many days will 150 men make 5 miles ? 30 days. Answer.

PRACTICE.

Example.—173 at 2s. 6¾d.

2	$\frac{1}{10}$	173			
6	¼	17	6	0	
½	$\frac{1}{12}$	4	6	6	
¼	½		7	2½	
			3	7¼	
		£22	3	3¾	Answer.

2s. = $\frac{1}{10}$ of £1 ; 6d. = ¼ of 2s. ; ½d. = $\frac{1}{12}$ of 6d. ; and ¼q. = ½ of ½d. Arrange as in the solution, divide by short division, and add the several quotients.

EXERCISES.

No.			s.	d.		£	s.	d.
1	614	at	1	8	Answer	51	3	4
2	166	,,	6	8	,,	55	6	8
3	872	,,	0	1½	,,	5	9	0
4	714	,,	0	0¼	,,	0	14	10½
5	292	,,	1	1¼	,,	16	2	5
6	671	,,	1	8¾	,,	58	0	3¼

INTEREST, DISCOUNT.

Example 1.—What is the simple interest of £214 15s. 6d. at 5 per cent. per annum ?

£		£		£	s.	d.		£	s.	d.
100	:	5	: :	214	15	6	Answer	10	14	9·3
						5				
			1,00)	10,73	17	6				
				10·73						
				20						
				14·77						
				12						
				9·30						

Example 2.—What is the discount on a bill of £142 15s. 10d. at 7½ per cent.

$$\begin{array}{rrrl}
 & \pounds & \text{s.} & \text{d.} \\
2) & 142 & 15 & 10 \\
 & & & 7\frac{1}{2} \\
\hline
 & 999 & 10 & 10 \\
 & 71 & 7 & 11 \\
\hline
1,00) & 10,70 & 18 & 9 \\
\hline
 & 10 \cdot 70 & & \text{Answer } \pounds 10 \text{ 14s. } 2 \cdot 25\text{d.} \\
 & 20 & & \\
\hline
 & 14 \cdot 18 & & \\
 & 12 & & \\
\hline
 & 2 \cdot 25 & & \\
\hline
\end{array}$$

INVOLUTION.

Example 1. 9^2

$$\begin{array}{rl}
9 & \\
9 & \\
\hline
81 & \text{Answer.} \\
\hline
\end{array}$$

Example 2. 4^3

$$\begin{array}{rl}
4 & \\
4 & \\
\hline
16 & \\
4 & \\
\hline
64 & \text{Answer.} \\
\hline
\end{array}$$

Example 3. 5^4

$$\begin{array}{rl}
5 & \\
5 & \\
\hline
25 & \\
5 & \\
\hline
125 & \\
5 & \\
\hline
625 & \text{Answer.} \\
\hline
\end{array}$$

EXERCISES.

1. If 454 tons of Welsh coal in the bunkers be sufficient for a voyage cf 2900 miles, and Lancashire coal be for space in the proportion of 46 to 40, and inferior in quality as 8·7 to 10·7 ; what distance will the bunkers carry her if filled with Lancashire coal ? 2050·39 miles. Answer.

2. If 100 make 8 miles of road in 27 days ; in how many days will 150 men make 5 miles ? 30 days. Answer.

PRACTICE.

Example.—178 at 2s. 6¾d.

		£	s.	d.	
2	$\frac{1}{10}$	178			
6	¼	17	6	0	
½	$\frac{1}{12}$	4	6	6	
¼	½		7	2½	
			3	7¼	
		£22	3	3¾	Answer.

2s. = $\frac{1}{10}$ of £1 ; 6d. = ¼ of 2s. ; ½d. = $\frac{1}{12}$ of 6d. ; and ¼q. = ½ of ½d. Arrange as in the solution, divide by short division, and add the several quotients.

EXERCISES.

No.			s.	d.		£	s.	d.
1	614	at	1	8	Answer	51	8	4
2	166	,,	6	8	,,	55	6	8
3	872	,,	0	1½	,,	5	9	0
4	714	,,	0	0¼	,,	0	14	10½
5	292	,,	1	1¼	,,	16	2	5
6	671	,,	1	8¾	,,	58	0	3¼

INTEREST, DISCOUNT.

Example 1.—What is the simple interest of £214 15s. 6d. at 5 per cent. per annum ?

£		£		£	s.	d.		£	s.	d.
100	:	5	: :	214	15	6	Answer	10	14	9·3
						5				
			1,00)	10,73	17	6				

10·73
20

14·77
12

9·30

Example 2.—What is the discount on a bill of £142 15s. 10d. at 7½ per cent.

£ s. d.
2)142 15 10
7½

999 10 10
71 7 11

1,00)10,70 18 9

10·70 Answer £10 14s. 2·25d.
20

14·18
12

2·25

INVOLUTION.

Example 1. 9^2

9
9

81 Answer.

Example 2. 4^3

4
4

16
4

64 Answer.

Example 3. 5^4

5
5

25
5

125
5

625 Answer.

EXAMINATION OF ENGINEERS.

PRELIMINARY NOTE.

For the sake of convenience of reference the different Articles in the following work are numbered with large Arabic numerals; when an Article has several subdivisions under one head, they are numbered with small numerals; or, the capital letters A, B, C and so on, are placed at the right side of the page: thus Art. 17 means that Art. 17 is referred to; again, Art. 1. 4, means that the 4th subdivision of Article 1. has to be examined.

ARTICLE 1.

The following signs are used in this work.

1. The mark =, read *equal to* is the sign of equality, and it signifies that the quantities between which it is placed are equal.

2. The mark +, read *plus*, is the sign of addition, and it signifies that the quantities between which it is placed have to be added together; thus $9+24=33$.

3. The mark —, read *minus*, is the sign of subtraction, and it signifies that the latter of two quantities between which it is placed has to be subtracted from the former; thus $33-6=27$.

4. The mark X read *multiplied by*, is the sign of multiplication, and it signifies that the quantities between which it is placed have to be multiplied together; thus $8 \times 3 = 24$.

5. The mark ÷, read *divided by*, is the sign of division, and it signifies that the former of two quantities between which it is placed has to be divided by the latter; thus $18 \div 2 = 9$.

6. Division is often denoted thus $\frac{18}{2} = 9$; where the number above the line is divided by that below.

7. The mark ° placed thus 27° is read 27 degrees.

8. ∴ are used for the word *therefore*.

9. The marks ′ ″ placed thus 6′ 2″ are read 6 feet 2 inches.

ARTICLE 2.

EXERCISES IN THE USE OF THE SIGNS.

1. $(9 + 3{\cdot}7) - 3 \times 2 = 12{\cdot}7 - 6 = 6{\cdot}7$ Answer.

2. $243 \div 3 + 100 - 13 \times 4$
$= 81 + 100 - 52$

$$\begin{array}{r} 81 \\ 100 \\ \hline 181 \\ -52 \\ \hline 129 \text{ Answer.} \\ \hline \end{array}$$

NOTE. When no sign is prefixed to a quantity the + sign is always understood.

3. $28 \div 7 + 7 - 2\,(18 - 17)$
$= 4 + 7 - 2 = 11 - 2 = 9$ Answer.

4. $42 - (18 - 6) + 7 \times (20 - 4)$
$= 42 - 12 + 7 \times 16$
$= 30 + 112 = 142$ Answer.

5. $22 \div 11 + 7 \times 6 - 2$
$= 2 + 42 - 2 = 42$ Answer.

6. $(101 - 20)^{\frac{1}{2}} + 2 \times 7$
$= 81^{\frac{1}{2}} + 14 = 9 + 14 = 23$ Answer.

7. $(7 - 2)^3 - (14 - 3)^2$
$= 5^3 - 11^2 = 125 - 121 = 4$ Answer.

8. $24 \div 4 - 6 \times (69 - 68)$
$= 6 - 6 \times 1 = 6 - 6 = 0$ Answer.

9. $\frac{3 \times 1 \times 34}{5 \times 16 \times 1} = \frac{102}{80} = 1\frac{22}{80} = 1\frac{11}{40}$ Answer.

10. $60 \times 9 - 42 + 39 = 540 - 3 = 537$ Answer.

11. $60 \times 9 - {\cdot}42 + {\cdot}39 = 540 - {\cdot}03 = 539{\cdot}97$ Answer.

12. $(46 - 10)^{\frac{1}{2}} + (25 - 9)^{\frac{1}{2}} = 36^{\frac{1}{2}} + 16^{\frac{1}{2}} = 6 + 4 = 10$ Answer.

ARTICLE 3.

ALGEBRA.

In Algebra the signs used in Arithmetic are also used, and the letters of the alphabet are used to denote numbers.

1. Thus the expression $a+b$, means that the number denoted by b is to be added to that denoted by a. Let 2 be the number denoted by b and 6 that denoted by a; then by substituting these values of a and b in the expression $a+b$ we have the expression $6+2$; that is 2 and 6 have to be added together.

2. The expression $a-b$, means that the number denoted by b is to be subtracted from that denoted by a. Let a and b have the same values as in Art. 1, then $a-b=6-2$; that is 2 has to be subtracted from 6.

3. The expression $a+b=c$, means that the sum of the numbers denoted by a and b is equal to the number denoted by c. Let a and b have the same values as in the preceding Arts., then $6+2=8$; so that $c=8$.

4. The expression $a-b=c$, means that the difference between the numbers denoted by a and b is equal to the number denoted by c. Let a and b have the same values as before, then $6-2=4$; so that in this case $c=4$.

5. The expression $a\,b$ means that the numbers denoted by a and b must be multiplied together. Let a and b have the same values as before; then $a\,b=6\times 2$. Here the sign × is used when numbers have to be multiplied together. Sometimes the expression $a{\cdot}b$ is used to denote that a and b have to be multiplied together.

6. The expression $\frac{a}{b}$ means that the number denoted by a must be divided by that denoted by b. Let a and b have the same values as before, then $\frac{a}{b}=\frac{6}{2}=3$.

7. The expression a^2 means that the number denoted by a must be multiplied by itself; thus if $a=4$, then

$$a^2=a\,a=4^2=4\times 4=16.$$

8. The expression a^3 means that the number denoted by a must be multiplied twice by itself; thus if $a=4$ then

$$a^3=a\,a\,a=4^3=4\times 4\times 4=64$$

9. a^2 is called the square of a or the second power of a. a^3 is called the cube of a, or the third power of a.

10. The expression $\sqrt{a}$ is called the square root of a, and it represents a number such that if multiplied by itself the product will be a. Let $a=16$ then $\sqrt{a}=\sqrt{16}=4$; for $4\times 4=16$.

11. The expression $a\{(b+c)-(d+e)\}$ means that the numbers denoted by d and e have to be added together, and their sum subtracted from the

sum of the numbers denoted by b and c, then the difference of these sums has to be multiplied by the number denoted by a.

Let $a = 6$, $b = 5$, $c = 4$, $d = 3$, and $e = 2$; then substitute these values in the above expression and we have

$$6\times\left\{(5+4)-(3+2)\right\}=6\times(9-5)=6\times4=24$$

ON EQUATIONS.

An *Equation* is an expression stating that two quantities between which the sign of equality is placed are equal.

Thus the expression $a+b=c-d$ is an equation.

The part of an equation at the left side of the sign of equality is called the *left*, or *first*, *side* of the equation, and the other part is called the *right*, or *second side*.

The word *Formula* is often used instead of the word Equation.

ON FINDING THE NUMERICAL VALUES OF ALGEBRAICAL FORMULÆ.

EXERCISES.

1. Find the value of $l\,b$, where $l=6$, $b=4$.

The expression $l\,b$, means that the numbers represented by l and b respectively have to be multiplied together; as follows.

$l\,b=6\times4=24$ Answer.

2. Find the value of $\frac{a}{b}$, where $a=24$, $b=4$.

The expression $\frac{a}{b}$ means that the number represented by a has to be divided by the number represented by b; as follows:

$$\frac{a}{b}=\frac{24}{4}=6 \text{ Answer.}$$

3. Find the value of $\frac{a}{l}$, where $a=24$, $l=6$.

$$\frac{a}{l}=\frac{24}{6}=4 \text{ Answer.}$$

4. Find the value of ·7854 d^2, where $d=24$. Proceed as follows:

·7854 d^2=·7854×24×24.

24	·7854
24	576
96	47124
48	54978
576	39270
	452·3904 Answer.

5. Find the value of $\frac{a}{\cdot7854}$, and of $\sqrt{(\frac{a}{\cdot7854})}$; where a=452·3904?

Proceed as follows:

$$\frac{a}{\cdot7854}=\frac{452\cdot3904}{\cdot7854}$$

·7854)452·3904(576 Answer
39270
59690
54978
47124
47124

Also, $\sqrt{(\frac{a}{\cdot7854})}=\sqrt{(\frac{452\cdot3904}{\cdot7854})}=\sqrt{(576)}$

576(24 Answer.
4
44)176
176

6. Find the value of 3·1416 d, where $d=6$.

3·1416 d=3·1416×6
3.1416
6
18·8496 Answer.

7. Find the value of $\frac{c}{3\cdot1416}$ where c=18·8496.

$$\frac{c}{3\cdot1416}=\frac{18\cdot8496}{3\cdot1416}$$

3·1416)18·8496(6 Answer.
18 8496

8. Find the value of $l\,b\,h$, where $l=4$, $b=3$, and $h=2$.

$l\,b\,h=4\times3\times2$

$$\begin{array}{r} 4\\ 3\\ \hline 12\\ 2\\ \hline 24 \\ \hline \end{array}\ \text{Answer.}$$

9. Find the value of $\dfrac{v}{b\,h}$, where $v=24$, $b=3$, and $h=2$.

$$\frac{v}{b\,h}=\frac{24}{3\times2}=\frac{24}{6}=4\ \text{Answer.}$$

10. Find the value of $\dfrac{v}{l\,h}$ where $v=24$, $l=4$, and $h=2$.

$$\frac{v}{l\,h}=\frac{24}{4\times2}=\frac{24}{8}=3\ \text{Answer.}$$

11. Find the value of $\dfrac{v}{l\,b}$ where $v=24$, $l=4$, and $b=3$.

$$\frac{v}{l\,b}=\frac{24}{4\times3}=\frac{24}{12}=2\ \text{Answer.}$$

12. Find the value of $\cdot7854\,d^2\,h$, where $d=6$, $h=8$.

$\cdot7854\,d^2\,h=\cdot7854\times6\times6\times8$

$$\begin{array}{r} \cdot7854\\ 36=6\times6\\ \hline 47124\\ 23562\ \ \\ \hline 28\cdot2744\\ 8\\ \hline 226\cdot1952 \\ \hline \end{array}\ \text{Ans.}$$

13. Find the value of $\dfrac{v}{\cdot7854\,h}$, where $v=226\cdot1952$, and $h=8$.

$$\frac{v}{\cdot7854\,h}=\frac{226\cdot1952}{\cdot7854\times8}$$

$$\begin{array}{r} \cdot7854 \\ 8 \\ \hline 6\cdot2832 \\ \hline \end{array} \qquad \begin{array}{l} 6\cdot2832)226\cdot1952(36 \text{ Answer.} \\ 188496 \\ \hline 376992 \\ 376992 \\ \hline \end{array}$$

14. Find the value of $\frac{v}{\cdot7854\,d^2}$, where $v=226\cdot1952$ and $d^2=36$.

$$\frac{v}{\cdot7854\,d^2}=\frac{226.1952}{\cdot7854\times36}$$

$$\begin{array}{r} \cdot7854 \\ 36 \\ \hline 47124 \\ 23562 \\ \hline 28\cdot2744 \\ \hline \end{array} \qquad \begin{array}{l} 28\cdot2744)226\cdot1952(8 \text{ Answer.} \\ 226\,1952 \\ \hline \end{array}$$

15. Find the value of $\cdot7854\,(D^2-d^2)\,h$, where $D=16$, $d=12$, and $h=6$.

$$\begin{array}{r} D=16 \\ 16 \\ \hline 96 \\ 16 \\ \hline D^2=256 \\ \hline \end{array} \qquad \begin{array}{r} d=12 \\ 12 \\ \hline d^2=144 \\ \hline \end{array} \qquad \begin{array}{r} D^2=256 \\ d^2=144 \\ \hline D^2-d^2=112 \\ \hline \end{array}$$

$$\therefore\ \cdot7854\,(D^2-d^2)\,h=\cdot7854\,(16^2-12^2)\times6=\cdot7854\times112\times6.$$

$$\begin{array}{r} \cdot7854 \\ 112 \\ \hline 15708 \\ 7854 \\ 7854 \\ \hline 87\cdot9648 \\ 6 \\ \hline 527\cdot7888 \text{ Answer.} \\ \hline \end{array}$$

16. Find the value of $3\cdot1416\,d\,h$, where $d=6$, and $h=4$.

$$3\cdot1416\,d\,h=3\cdot1416\times6\times4$$

$$\begin{array}{r} 3{\cdot}1416 \\ 6 \\ \hline 18{\cdot}8496 \\ 4 \\ \hline 75{\cdot}3984 \end{array} \text{ Answer.}$$

17. Find the value of $\frac{P}{2}+6\,M-N\div4$; where $P=6$, $M=4$, $N=12$.

$$\frac{P}{2}+6\,M-N\div4=\frac{6}{2}+6\times4-12\div4$$

$$=3+24-3= \qquad 24 \text{ Answer.}$$

18. Find the value of $(p-q)+6\,s-\frac{x}{y}$; when $p=10$, $q=4$, $s=3$, $x=12$, and $y=4$.

$$(p-q)+6\,s-\frac{x}{y}=(10-4)+6\times3-\frac{12}{4}$$

$$=6+18-3= \qquad 21 \text{ Answer.}$$

19. Find the value of $\frac{a\,b\,c}{d}+\frac{m}{n}-\frac{p}{q}$, where $a=2$, $b=3$, $c=4$, $d=6$, $m=6$, $n=2$, $p=28$, and $q=7$.

$$\frac{a\,b\,c}{d}+\frac{m}{n}-\frac{p}{q}=\frac{2\times3\times4}{6}+\frac{6}{2}-\frac{28}{7}$$

$$=4+3-4= \qquad 3 \text{ Answer.}$$

20. Find the value of $\frac{(T-t)\,(T-50)\,(t-50)}{100000}$, where $T=154$, $t=112$.

$$\frac{(T-t)\,(T-50)\,t-50)}{100000}=\frac{(154-112)\,(154-50)\,(112-50)}{100000}$$

$$=\frac{42\times104\times62}{100\,000}$$

$$\begin{array}{r}
42 \\
104 \\
\hline
168 \\
420 \\
\hline
4368 \\
62 \\
\hline
8736 \\
26208 \\
\hline
1,00\,000)2,70816 \\
\hline
2{\cdot}70816 \\
\hline
\end{array}$$

Answer.

ARTICLE 5.

GIVEN ALL THE QUANTITIES IN A FORMULA EXCEPT ONE TO FIND THE UNKNOWN QUANTITY.

ARTICLE 6.

The formula for the area of a rectangle is

$$a = l\,b \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{A}$$

Where a = area in square inches, square feet, &c.

$$\left.\begin{array}{l} l = \text{length} \\ b = \text{breadth} \end{array}\right\} \text{in lineal inches, lineal feet, \&c.}$$

Here a is the initial letter of the word area, l is that of the word length, and b is that of the word breadth.

This notation is very useful; and generally the initial letters of the given and required quantities are used in the formulas when it is convenient to do so.

The preceding formula may be denoted by the capital letter A at the side of the page; and when the length and breadth are known the formula shows that their product is the area.

Again; suppose the length is unknown while the area and breadth are known; then, shift l to the left side of the equation and a to the right side, draw a line under a and place b underneath the line as follows:

$$l = \frac{a}{b} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{B}$$

This formula shows that the quotient of a divided by b is the length.

In like manner when the breadth is unknown, the following formula:

$$b = \frac{a}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad C$$

shews that the quotient of a divided by l is the breadth.

ARTICLE 7.

AREA OF A CIRCLE.

The formulas for the area and diameter of a circle are

$$a = \cdot7854\ d^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad A$$

$$d^2 = \frac{a}{\cdot7854} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad B$$

$$d = \sqrt{\left(\frac{a}{\cdot7854}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad C$$

Where a = area; in square inches, square feet, &c.
d = diameter; in lineal inches, lineal feet, &c.

When formula A is known, formula B is derived from it in the same manner as formulæ B and C are from formula A in Art. 6.

ARTICLE 8.

CIRCUMFERENCE OF THE CIRCLE.

The formulæ for the circumference and diameter of a circle are

$$c = 3\cdot1416\ d \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad A$$

$$d = \frac{c}{3\cdot1416} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad B$$

$$\text{Where } \left.\begin{aligned} c &= \text{circumference} \\ d &= \text{diameter} \end{aligned}\right\}\ \text{in lineal measure}$$

Formula B is derived from formula A in the same manner as is done in Arts. 6 and 7.

ARTICLE 9.

VOLUMES OF SOLIDS.

RECTANGULAR SOLID.

The formula for the volume of a rectangular solid is

$$v = l\ b\ h \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad A$$

Where v = volume, in cubic inches, cubic feet, &c.

$$\left.\begin{aligned} l &= \text{length} \\ b &= \text{breadth} \\ h &= \text{height} \end{aligned}\right\}\ \text{in lineal inches, lineal feet, \&c.}$$

In a similar manner as in Arts. 6 and 7.

From formula A we derive the following formulæ

$$l = \frac{v}{b\,h} \ldots\ldots\ldots\ldots \text{B}$$

$$b = \frac{v}{l\,h} \ldots\ldots\ldots\ldots \text{C}$$

$$h = \frac{v}{l\,b} \ldots\ldots\ldots\ldots \text{D}$$

ARTICLE 10.

VOLUME OF CYLINDER.

The formula for the volume of a cylinder is

$$v = {\cdot}7854\ d^2\ h \ldots\ldots\ldots\ldots \text{A}$$

Where v = volume; in cubic measure.
d = diameter, h = height } in lineal measure.

From formula A we obtain the following formulæ

$$d^2 = \frac{v}{{\cdot}7854\,h} \ldots\ldots\ldots\ldots \text{B}$$

$$d = \sqrt{\left(\frac{v}{{\cdot}7854\,h}\right)} \ldots\ldots\ldots\ldots \text{C}$$

$$h = \frac{v}{{\cdot}7854\,d^2} \ldots\ldots\ldots\ldots \text{D}$$

ARTICLE 11.

VOLUME OF HOLLOW CYLINDER.

The formula for the volume of a hollow cylinder is

$$v = {\cdot}7854\ (D^2 - d^2)\ h \ldots\ldots\ldots\ldots \text{A}$$

Where v = volume; in cubic measure.
D = outer diameter, d = inner diameter, h = height } in lineal measure.

From formula A we obtain

$$h = \frac{v}{{\cdot}7854\,(D^2 - d^2)} \ldots\ldots\ldots\ldots \text{B}$$

ARTICLE 12.

SURFACE OF CYLINDER.

The formula for the convex surface of a cylinder is

$$s = 3{\cdot}1416\, d\, h \ldots\ldots \text{A}$$

Where s = surface; in square measure.
d = diameter } in lineal measure.
h = height }

From formula A we obtain

$$d = \frac{s}{3{\cdot}1416\, h} \ldots\ldots \text{B}$$

$$h = \frac{s}{3{\cdot}1416\, d} \ldots\ldots \text{C}$$

ARTICLE 13.

PUMPS.

The formula for the volume of water, in cubic feet, extracted in an hour is

$$v = \frac{{\cdot}7854\, d^2 s\, n\, f \times 60}{1728} \ldots\ldots \text{A}$$

Where v = volume of water; in cubic feet.
d = diameter of pump } in inches.
s = length of stroke }
n = number of strokes per minute.
f = fraction that the pump is full.
60 = minutes in an hour.
1728 = cubic inches in a cubic foot.

The constants $\frac{{\cdot}7854 \times 60}{1728} = {\cdot}0272708$ nearly.

Hence, by substituting ·0272708 in formula A, we have

$$v = {\cdot}0272708\, d^2 s\, n\, f \ldots\ldots \text{B}$$

which is nearly correct.

From formula A we obtain the following formulæ:

$$d^2 = \frac{1728\, v}{{\cdot}7854\, s\, n\, f \times 60} \ldots\ldots \text{C}$$

$$d = \sqrt{\left(\frac{1728\, v}{{\cdot}7854\, s\, n\, f \times 60}\right)} \ldots\ldots \text{D}$$

$$s = \frac{1728\,v}{\cdot 7854\,d^2\,n\,f \times 60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots E$$

$$n = \frac{1728\,v}{\cdot 7854\,d^2\,s\,f \times 60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots F$$

$$f = \frac{1728\,v}{\cdot 7854\,d^2\,s\,n \times 60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots G$$

ARTICLE 14.

TO FIND HOW MANY TONS OF WATER THE PUMP WILL LIFT PER HOUR.

Since by "Hints to Engineer Candidates" No. 5, one cubic feet of fresh water weighs, 62½ lbs., and that 2240 lbs. = 1 ton; therefore multiply formula A, Art. 13, by 62·5 ÷ 2240 and we have the following formula for the tons of fresh water pumped out in an hour.

$$\text{Tons} = \frac{\cdot 7854\,d^2\,s\,n\,f \times 60 \times 62{\cdot}5}{1728 \times 2240} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots A$$

Again; since by the "Hints," Thirty-five cubic feet of sea water weighs 1 ton; therefore divide formula A, Art. 13, by 35, and we obtain the following formula for the tons of sea water pumped out in an hour.

$$\text{Tons} = \frac{\cdot 7854\,d^2\,s\,n\,f \times 60}{1728 \times 35} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots B$$

ARTICLE 15.

TO FIND THE TIME IN WHICH A PUMP WILL EMPTY A TANK.

For the solution of this question we have the formula.

$$\text{Time; in hours} = \frac{\text{cubic feet of water in tank}}{\text{cubic feet pumped out in an hour}} \ldots\ldots A$$

If the water in the tank be given in tons; then, since the water is salt, the cubic feet are found by multiplying the tons by 35.

If the pump be double acting, then formula A in Art. 13 must be multiplied by 2.

Again; to divide by a fraction is equivalent to multiply by the fraction inverted; therefore to divide by $\frac{1}{1728}$ in formula A Art. 13 is equivalent to multiply by $\frac{1728}{1}$; and since f in the same formula is a fraction, let it be equal to $\frac{p}{q}$, then $\frac{p}{q}$ inverted becomes $\frac{q}{p}$.

Making these substitutions in formula A, Art. 13, and placing the altered formula in the denominator of the formula A of the present Art., we have

$$\text{Time; in hours} = \frac{\text{tons} \times 85 \times 1728 \times q}{\cdot 7854\, d^2\, s\, n \times 60 \times p \times 2} \ldots\ldots\ldots\ldots\ldots \text{B}$$

If the dimensions of the tank be given; then, by formula A, Art. 9, we have the cubic feet of water in the tank $= l\, b\, h$; thus formula B becomes

$$\text{Time; in hours} \; \frac{l\, b\, h \times 1728 \times q}{\cdot 7854\, d^2\, s\, n \times 60\, p \times 2} \ldots\ldots\ldots\ldots\ldots\ldots \text{C}$$

Article 16.

GIVEN THE TIMES IN WHICH TWO PUMPS WORKING SEPARATELY WILL EACH DISCHARGE THE WATER OUT OF A TANK; TO FIND THE TIME IN WHICH THEY WILL DISCHARGE IT WHEN BOTH PUMPS ARE WORKING TOGETHER.

Let a = time in which the first working alone will discharge it.
b = „ „ second „ „
x = „ „ both working together „

Then $\frac{x}{a}$ = part discharged by the first in x hours.
$\frac{x}{b}$ = „ „ second „

And the sum of these two parts is the whole water discharged, which we shall denote by 1.

$$\text{Thus } \frac{x}{a} + \frac{x}{b} = 1 \;\therefore\; b\,x + a\,x = a\,b \;\therefore\; x = \frac{a\,b}{a+b} \ldots\ldots\ldots\ldots\ldots \text{A}$$

ARTICLE 17.

HORSE POWER.

The formula for the Indicated Horse Power is

$$H\,P = \frac{\cdot 7854\, d^2 p\, s\, r \times 2}{33000} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{A}$$

Where $H\,P$ = horse power.
d = diameter of cylinder; in inches.
p = pressure of steam per square inch on cylinder; in lbs.
s = length of stroke; in feet.
r = revolutions per minute.

In formula A the quantity $H\,P$ is unknown and d^2, p, s, r are known.

Suppose d^2 to be unknown and the other quantities to be known; shift d^2 to the left side of the equation, and $H\,P$ to the right side, draw a line under $H\,P$ and place 33000 above the line, and all the other quantities except d^2 underneath the line; as follows

$$d^2 = \frac{33000\, H\,P}{\cdot 7854\, p\, s\, r \times 2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{B}$$

$$\therefore\ d = \sqrt{\left(\frac{33000\, H\,P}{\cdot 7854\, p\, s\, r \times 2}\right)} \ldots\ldots\ldots\ldots\ldots\ldots \text{C}$$

In like manner.

$$p = \frac{33000\, H\,P}{\cdot 7854\, d^2 s\, r \times 2} \ldots\ldots\ldots\ldots\ldots\ldots \text{D}$$

$$s = \frac{33000\, H\,P}{\cdot 7854\, d^2 p\, r \times 2} \ldots\ldots\ldots\ldots\ldots\ldots \text{E}$$

$$r = \frac{33000\, H\,P}{\cdot 7854\, d^2 p\, r \times 2} \ldots\ldots\ldots\ldots\ldots\ldots \text{F}$$

$\cdot 7854 \div 33000 = \cdot 0000238$; hence by substituting this value in formula A we have

$$H\,P = \cdot 0000238\, d^2 p\, s\, r \times 2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{G}$$

Hence

$$d^2 = \frac{H\,P}{\cdot 0000238\, p\, s\, r \times 2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{H}$$

$$p = \frac{H\,P}{\cdot 0000238\, d^2 s\, r \times 2} \ldots\ldots\ldots\ldots\ldots\ldots \text{I}$$

$$s = \frac{H\,P}{\cdot 0000238\, d^2 p\, r \times 2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{J}$$

$$r = \frac{H\,P}{\cdot 0000238\, d^2 p\, s \times 2} \ldots\ldots\ldots\ldots\ldots\ldots \text{K}$$

ARTICLE 18.

Given the height of a mast head above the sea when the ship is upright, and also its height when she is inclined; to find what she would blow off at.

Let $\frac{w}{a} = \frac{w}{\cdot 7854\,d^2} = P$ = pressure per square inch on the valve, when ship is upright; in lbs.

p = pressure per square inch on the valve, when ship is inclined; in lbs.
w = weight on valve when the ship is upright; in lbs.
a = area of valve = $\cdot 7854\,d^2$; in sq. inches.
d = diameter of valve, in inches.
H = height of mast when the ship is upright; in feet.
h = ,, ,, ,, inclined; in feet.

$$\text{Then } \frac{p}{P} = \frac{h}{H} \therefore p = \frac{h\,P}{H} = \frac{\frac{h\,w}{\cdot 7854\,d^2}}{H}$$

We thus obtain the *Formula*

$$p = \frac{h\,w}{H \cdot 7854\,d^2}$$

ARTICLE 19.

TO FIND THE NUMBER OF BOLTS IN A CYLINDER COVER.

For the solution of this question we must have the pressure that all the bolts will bear equal to the pressure of the steam on the area of the cylinder cover; thus we obtain the following equations:

$$n \cdot 7854\,d^2\,s = \cdot 7854\,D^2\,p$$

$$\therefore n = \frac{\cdot 7854\,D^2\,p}{\cdot 7854\,d^2\,s} = \frac{D^2\,p}{d^2\,s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots A$$

Where D = diameter of cylinder cover } in inches.
d = ,, bolts } in inches.
p = pressure per square inch on cylinder cover } in lbs.
s = strain that every bolt will bear } in lbs.

ARTICLE 20.

Given the I. H. P. of an engine, the lbs. weight of steam used per hour, per I. H. P., and the temperatures of the injection water and discharge water.

Then, if 1 lb. of steam give out sufficient heat to raise 1000 lbs. of water 1° Fahrenheit; find how many tons of injection water are used in a certain number of hours.

Let T = tons of injection water used in the given hours.
h = horse power.
s = steam used per hour per I. H. P. } in lbs.
w = water heated 1° }
t = time ; in hours.
d = difference of temperatures.

Then, the product of the lbs. of water used to condense 1 lb of steam, multiplied by the difference of temperatures is equal to the product of 1000 lbs. by 1°; that is, it is equal to 1000.

$$\therefore \frac{1000}{d} = \text{lbs. of water used to condense 1 lb. of steam.}$$

And $h\,s$ = lbs of steam condensed per hour.

$$\therefore \frac{h\,s\,1000}{d} = \text{lbs. of injection water used per hour.}$$

Multiplying this fraction by the number of hours per day we get the number of lbs. per day, which being divided by 2240 gives us the number of tons of cold water used per day ; thus we obtain the formula

$$T = \frac{h\,s\,w\,t}{2240\,d} \quad \ldots\ldots\ldots\ldots \text{A}$$

ARTICLE 21.

THE LEVER.

In figure 1, let A B be the ends of a lever resting on a fulcrum F, P the power applied at A, W the weight to be lifted at B ; then

$$P \times A\,F = W \times B\,F \quad \ldots\ldots\ldots\ldots \text{A}$$

$$\therefore P = \frac{W \times B\,F}{A\,F} \quad \ldots\ldots\ldots\ldots \text{B}$$

If the lever be assumed to have no weight, we have

$P + W$ = weight pressing on the fulcurm C

If the weight of the lever = L, then

$L + P + W$ = weight pressing on the fulcrum .... D

ARTICLE 22.

Given the number of gallons in a tank; to find its volume and height Since there are 6¼ gallons in 1 cubic foot.

$$\therefore v = \frac{g}{6{\cdot}25} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{A}$$

Where v = volume; in cubic feet.
g = gallons in tank.

By Article 9, formula A

$$v = l\,b\,h \;\therefore\; l\,b\,h = \frac{g}{6{\cdot}25}$$

$$\therefore h = \frac{g}{l\,b \times 6{\cdot}25} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{B}$$

ARTICLE 23.

Given the diameter of the stays of a boiler, their distance apart from centre to centre, and the strain per square inch section of stay; to find the pressure per square inch on the boiler.

$$\text{Let } \left.\begin{array}{l} d = \text{diameter of stay} \\ s = \text{space apart} \end{array}\right\} \text{in inches.}$$

$$\left.\begin{array}{l} S = \text{strain on stay, per square inch} \\ p = \text{pressure on boiler} \quad ,, \end{array}\right\} \text{in lbs.}$$

Then

$$\cdot 7854\, d^2 S = s^2 p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{A}$$

$$p = \frac{\cdot 7854\, d^2 S}{s^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{B}$$

$$s = \sqrt{\left(\frac{.7854\, S}{p}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{C}$$

$$d = \sqrt{\left(\frac{s^2 p}{\cdot 7854\, S}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{D}$$

$$S = \frac{s^2 p}{\cdot 7854\, d^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{E}$$

ARTICLE 24.

TO FIND THE AVERAGE TIME THAT EVERY PORTION OF STEAM REMAINS IN THE SUPERHEATER.

Let t = time; in seconds, that the steam is in the superheater.
c = lbs of coals burnt in 1 hour for every sq. foot of grate.
w = lbs of water evaporated for every lb. of coal.
n = cubic feet of superheater for every square foot of grate.
s = times volume of steam is greater than that of water.
62·5 = weight of 1 cubic foot of fresh water, in lbs.
3600 = seconds in 1 hour.

Then

$c\,w$ = lbs. of water evaporated for every lb. of coal burnt in 1 hour.

$$\therefore \frac{c\,w}{62{\cdot}5} = \text{cubic feet of water evaporated.}$$

$$\therefore \frac{c\,w\,s}{62{\cdot}5} = \text{volume of steam.}$$

$$\therefore t : 3600 :: n : \frac{c\,w\,s}{62{\cdot}5}$$

$$\therefore t = \frac{n\,3600}{\dfrac{c\,w\,s}{62{\cdot}5}}$$

$$\therefore t = \frac{62{\cdot}5 \times n\,3600}{c\,w\,s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{A}$$

ARTICLE 25.

FOR STEAM ABOVE 12 LBS. PRESSURE ABOVE THE ATMOSPHERE.

The weight of steam that will escape in 70 seconds through an orifice one square inch in area is equal to the lbs. in the gross pressure of the steam. To find what breadth of opening a safety valve must rise to in order to allow the escape of a certain weight of steam in an hour.

Let g = gross pressure of steam.
s = lbs. of steam that escape in an hour.
d = diameter of valve } in inches.
h = height that valve must rise }

$$\begin{array}{lccccccc} & \text{Seconds} & & \text{Seconds} & & \text{lbs. that escape in 70 seconds} & & \text{lbs. that escape in 1 minute} \\ \text{Then,} & 70 & : & 60 & :: & g & : & \frac{60}{70}g = \frac{6}{7}g \end{array}$$

$$\therefore \frac{6}{7}g \times 60 = \frac{360}{7}g = \text{lbs. that escape in 1 hour.}$$

$$\begin{array}{lccccccc} & \text{lbs. that escape in 1 hour} & & \text{lbs. that have to escape in 1 hour} & & \text{square inch} & & \text{square inches for escape} \\ \text{Again,} & \frac{360g}{7} & : & s & :: & 1 & : & \frac{s}{\frac{360g}{7}} = \frac{7s}{360g} \end{array}$$

Now the valve when lifted forms a cylinder whose surface must be equal to the area for the escape of the steam; thus by Article 12, formula A, we have:

$$3{\cdot}1416\,d\,h = \frac{7s}{360\,g} \therefore h = \frac{7s}{3{\cdot}1416\,d\,360\,g} = \frac{s}{{\cdot}4488\,d\,360\,g}.$$

And $\cdot 4488 \times 360 = 161{\cdot}568$

$$\text{Therefore } h = \frac{s}{161{\cdot}568\,d\,g} \text{ ....A}$$

ARTICLE 26.

To what height must a safety valve be lifted in order to allow a free escape of steam equal to the area of the valve.

When the valve is lifted it forms a cylinder whose diameter is that of the valve.

Let d = diameter of cylinder.
h = height ,,

Then, by Article 7 formula A, and Article 12 formula A.

Area of valve = $\cdot 7854\,d^2$
Surface of cylinder = $3.1416\,d\,h$

And by the condition of the question

$$31416\,d\,h = {\cdot}7844\,d^2$$

$$\text{Therefore} \quad h = \frac{{\cdot}7854\,d^2}{3{\cdot}1416\,d} = \frac{d}{4} \text{ ....A}$$

ARTICLE 27.

Given the I. H. P. and the lbs. of steam used per I. H. P. per hour, to find how many inches of the stroke of the air pump will be full.

In this question it is required to find what *fraction* of the stroke is full; hence we have formula G, Article 13, and since the water from the condensed steam weighs the same as the steam did, and that 62½ lbs. of fresh water are equal in capacity to 1 cubic foot, therefore, for v in the formula substitute ($HP \times$ lbs. of steam per I. H. P. per hour) ÷ 62·5; thus the formula becomes

$$f = \frac{1728 \times HP \times \text{lbs. of steam per I. H. P. per hour}}{\cdot 7854 \times d^2 s\, n \times 60 \times 62{\cdot}5} \ldots \text{A}$$

ARTICLE 28.

TIME IN MINUTES THAT PRESSURE TAKES TO RISE.

Given the length, breadth, and depth of water in a rectangular boiler, suppose that one third of the space is taken up with furnaces and tubes, and the rest is water; the furnaces consume so many lbs. of coal per hour, every lb. of coal is equal to heating 12000 lbs. of water one degree Fahrenheit.

The difference between the temperatures at two different pressures of steam are given.

Required the time in which the pressure will rise from the lesser to the greater pressure if all the valves be shut and the fires in action?

$$\text{Let } \left.\begin{aligned} l &= \text{length of boiler} \\ b &= \text{breadth} \quad ,, \\ d &= \text{depth of water} \end{aligned}\right\} \text{in feet.}$$

t = difference of temperatures.

c = cwts. of coal burnt per hour.

$$\text{Then } l\,b\,d - \frac{1}{3}\,l\,b\,d = \frac{3\,l\,b\,d - l\,b\,d}{3} = \frac{2}{3}\,l\,b\,d = \text{cubic ft. of water}$$

$$\frac{2}{3}\,l\,b\,d \times 64 = \text{weight of salt water; in lbs.}$$

$$\frac{2}{3}\,\frac{l\,b\,d \times 64}{\times 12000} = \text{lbs. of coals required to heat it } 1^\circ$$

Let $p = \dfrac{2\,l\,b\,d \times 64\,t}{8 \times 12000}$ = lbs. of coals required to heat it $t°$

Let $q = c \times 112$ = lbs. of coals consumed per hour.

Then $p : q :: 60 \text{ minutes} : 60\dfrac{p}{q}$

Substitute the values of p and q and we have

Time required to raise the pressure $= \dfrac{2\,l\,b\,d \times 64 \times t \times 60}{8 \times 12000 \times c \times 112}$ ......a

And by cancelling

Time $= \dfrac{l\,b\,d\,t}{525\,c}$ ....A

If the water be fresh, put 62·5 in the place of 64 in equation a and cancel, and we have

Time $= \dfrac{l\,b\,d\,t \times 2{\cdot}5}{8 \times 4 \times c \times 112}$ ....B

DATA FOR EXAMINATION OF ENGINEERS.

SECOND CLASS.

1	12	643	742	417			
2	18	2	8	3	6		
3	5	3					
4	3 0 0	5 17 6	4 5 6	25			
5	19	90	20				
6	130	16	4	5	110		
7	592	25	28				
8	$\frac{13}{16}$	$1\frac{3}{4}$	$\frac{3}{8}$				
9	29	$3\frac{1}{2}$					
10	2	5 6	15 6	65			
11	1000	1	66	110			
12	52	36	9	700			

Remarks.—Fill up the blank space in No. (1) on the right hand page from No. 1 on the left hand page thus.

(1). Express in words 12, 643, 742, 417.

In like manner fill up the blanks in No. (2) on the right hand page from No. 2 on the left hand page; thus

(2). $18 \div 2 + 8 \times 3 - 6$.

And in the same manner fill all the blanks in the question from the data on the left hand page.

EXAMINATION PAPER.

SECOND CLASS.

Port	Class for which examined
Date	Candidate's Name

(1.) Express in words ?

Applicant's answer.

(2). ÷ + × — ?

Applicant's answer.

(3). The diameter of the piston rod at the bottom of the thread is " there are two bolts in the cross head each " diameter, what is the proportion of the area of the bolts to that of the rod ?

Applicant's answer.

(4). Add together £ s. d., £ s. d., and £ s. d. and divide the sum by ?

Applicant's answer.

(5). An engineer received £ as a bonus for his economy of coals, there were tons left at the end of the voyage, and they cost s. per ton ; what per cent did he receive ?

Applicant's answer.

PAPER I.

SECOND CLASS ENGINEERS.

(1.) Express in words 12, 643, 742, 417 ?

Twelve thousand six hundred and forty three millions, seven hundred and forty two thousands, four hundred and seventeen. Answer.

Remarks. The figures are easily read by separating them into groups containing three figures each as is done in the example.

(2.) $18 \div 2 + 8 \times 3 - 6$
$= 9 + 24 - 6$

$$\left.\begin{array}{r} 9 \\ 24 \end{array}\right\} \text{Add}$$

$$\begin{array}{rl} \hline 33 & \\ 6 & \text{Subtract} \\ \hline 27 & \text{Answer.} \\ \hline \end{array}$$

(3.) The diameter of the piston rod at the bottom of the thread is 5", there are two bolts in the cross head each 3" diameter; what is the proportion, or ratio, of the area of the bolts to that of the rod ?

SOLUTION.

$$\frac{\text{Area of section of bolts}}{\text{Area of section of rod}} = \frac{\cdot 7854 \times 3^2 \times 2}{\cdot 7854 \times 5^2} = \frac{3 \times 3 \times 2}{5 \times 5} = \frac{18}{25}$$

$$25 \begin{cases} 5)\underline{18} \\ 5)\ 3{\cdot}6 \end{cases}$$

$$\begin{array}{rl} \hline \cdot 72 & \text{Answer.} \\ \hline \end{array}$$

Note. ·72 : 1 : : area of bolts : area of rod.

Remarks. Formula A Article 7, expressed in words at length gives the following formula for finding the area of a circle.

$$\text{Area} = \cdot 7854 \times (\text{diameter})^2.$$

Hence we have

$$\frac{\text{Area of both bolts}}{\text{Area of piston rod}} = \frac{\cdot 7854 \times (\text{diameter of bolt})^2 \times 2}{\cdot 7854 \times (\text{diameter of piston rod})^2} = \frac{(\text{diameter of bolt})^2 \times 2}{(\text{diameter of piston rod})^2}$$

Since ·7854 is common to both numerator and denominator of the fraction, it may be omitted, or cancelled, from both of them. By substituting 3 for diameter of bolt, and 5 for diameter of piston rod, we have the question as it is put in the solution.

(4.) Add together £8 0s. 0d., £5 17s. 6d., and £4 5s. 6d., and divide the sum by 25.

$$\begin{array}{rrrrl} & \pounds & \text{s.} & \text{d.} & \\ & 8 & 0 & 0 & \\ & 5 & 17 & 6 & \\ & 4 & 5 & 6 & \\ \hline 25\left\{\begin{array}{l} 5) \\ \\ 5) \end{array}\right. & \begin{array}{r} 18 \\ \hline 2 \end{array} & \begin{array}{r} 3 \\ \hline 12 \end{array} & \begin{array}{r} 0 \\ \hline 7\cdot2 \end{array} & \\ \hline & 0 & 10 & 6\cdot24 & \text{Answer.} \end{array}$$

(5.) An engineer received £19 as a bonus for his economy of coals, there were 90 tons left at the end of the voyage and they cost 20s. per ton; what per cent. did he receive ?

90 tons left	As 90 : 19 : : 100
20 shillings per ton	100
2,0)180,0	9,0)190,0
£90 value of coals left	$21\cdot\dot{1}$ per cent. Answer.

(6.) The area of the boiler level is 130 square feet; a single acting donkey can pump up 16″ in the glass per hour; diameter of pump 4″; stroke 5″, revolutions per minute 110; what is the efficient stroke of the pump ?

For the solution of this question we have the formula G Article 13.

Expressing this formula in words at length, and observing that *f* is the fraction that the pump is full, or, in other words, it is the *efficient stroke* ; and that *v* is the volume, which is equal to the area multiplied by the height, and that we may express the inches of the height as the fraction of a foot by dividing them by 12 ; we have thus :

$$\text{Efficient stroke} = \frac{1728 \times \text{area} \times \text{height}}{\cdot7854 \times (\text{diameter})^2 \times \text{stroke} \times \text{revolutions} \times 60} \text{......} \; G$$

For the word area in formula G substitute the area given in the question, namely 130, for height substitute $\frac{16}{12}$, for (diameter)^2 substitute 4× 4, for stroke substitute 5, and for revolutions substitute 110 ; as follows

$$\text{Efficient stroke} = \frac{1728 \times 130 \times 16}{\cdot7854 \times 4 \times 4 \times 5 \times 12 \times 110 \times 60}$$

Cancel both numerator and denominator of this fraction by the numbers at the right side of the page as follows :

Divide by 12
12
6
10
4
4

$$\text{Efficient stroke} = \frac{\overset{\overset{\overset{2}{12}}{144}}{1728}\times\overset{13}{130}\times\overset{\overset{1}{4}}{16}}{\underset{\cdot1309}{\cdot7854}\times\underset{1}{4}\times\underset{1}{4}\times5\times\underset{1}{12}\times\underset{11}{110}\times\underset{5}{60}}$$

Hence

$$\text{Efficient stroke} = \frac{2\times13}{\cdot1309\times5\times11\times5}$$

Then proceed with the solution as follows.

$$\begin{array}{r} \cdot1309 \\ 55 = 5\times11 \\ \hline 6545 \\ 6545 \\ \hline 7\cdot1995 \\ 5 \\ \hline 35\cdot9975 \\ \hline \end{array} \qquad \begin{array}{r} 13 \\ 2 \\ \hline 35\cdot9975)26\cdot00000(\ \cdot722 \\ 25\ 19825\quad 5 \text{ inches stroke} \\ \hline 801750\ \ 3\cdot610 \\ 719950 \\ \hline 818000 \\ 719950 \\ \hline 98050 \\ \hline \end{array}$$

Answer ·722 of the stroke ; or 3·61 inches efficient.

(7.) When the temperature of the funnel is 592° the consumption is 25 tons per day ; after a few days it increases to 28 tons per day to raise the same amount of steam ; what is now the temperature of the funnel, nothing else having altered ; and what is the cause of the increased consumption ?

Note. Cost of evaporation is increased by (n) per cent. The alteration in the temperature of escaping gases alters to 22 (n) degrees.

$$\begin{array}{ccccccc} & & \text{tons} & & & & \\ & & 28 & & & & \\ & & 25 & & & & \\ \text{tons} & & \overline{} & & & \text{tons} & \\ 25 & : & 3 & : & : & 100 & \\ 1 & & 4 & & & 4 & \\ & & \overline{} & & & & \\ & & 12 \text{ per cent.} & & & & \end{array} \qquad \begin{array}{rl} 22 & \\ 12 & \\ \hline 264^\circ & \text{Alters} \\ 592 & \text{At first} \\ \hline 856 & \text{Answer.} \\ \hline \end{array}$$

(8.) What is the per centage of strength of a single rivetted seam, diameter of rivets $\frac{13}{16}$, pitch $1\frac{3}{4}$, and thickness of plate $\frac{7}{8}$.

$$\textit{Formula}\ \text{Per centage} = \frac{(\text{Pitch} - \text{diameter of rivets})\times100}{\text{Pitch}}$$

Hence, by substituting the numerical values of the pitch and diameter of rivets, we have

$$\frac{(1\frac{3}{4} - \frac{13}{16})\times 100}{1\frac{3}{4}} = \frac{(\frac{7}{4} - \frac{13}{16})\times 100}{\frac{7}{4}} = \frac{(\frac{28}{16} - \frac{13}{16})}{\frac{28}{16}}\times 100 =$$

$$\frac{\frac{(28 - 13)}{16}}{\frac{28}{16}}\times 100 = \frac{15\times 100}{28}.$$

$$\begin{array}{r} 15 \\ 100 \\ \hline 28\left\{\begin{array}{r} 7)1500 \\ \hline 4)214{\cdot}2857 \end{array}\right. \\ \hline \end{array}$$

Answer 53·5714 per cent.

Remarks. $1\frac{3}{4} = \frac{7}{4} = \frac{7\times 4}{4\times 4} = \frac{28}{16}$

$$\frac{28}{16} - \frac{13}{16} = \frac{28 - 13}{16} = \frac{15}{16}$$

(9.) What is the rubbing surface of a packing ring whose diameter is 29″, and width 3½?

Formula. Surface = 3·1416 × diameter × width.

Hence, by substitution in the formula, we have

Surface = 3·1416 × 29 × 3·5

$$\begin{array}{r} 3{\cdot}1416 \\ 29 \\ \hline 282744 \\ 62832 \\ \hline 91{\cdot}1064 \\ 3{\cdot}5 \\ \hline 4555320 \\ 2733192 \\ \hline \end{array}$$

$$144\left\{\begin{array}{l} 12)318{\cdot}87240 \text{ square inches.} \\ \hline 12)26{\cdot}5727 \end{array}\right.$$

12)318·87240 square inches. Answer.

or

2·2144 square feet. Answer.

Note. 144 square inches = 1 square foot.

(10.) There are 2 side bunkers each 5′ 6″ wide, and 15′ 6″ high, and they are to contain 65 tons of coals when full, what is the length of each; and how many cubic feet will you allow per ton ?

Answer. I will allow 45 cubic feet per ton.

By expressing formula B Article 9 in words at length; observing that v = cubic feet = tons × 45, since there are 45 cubic feet in 1 ton; and because their are 2 bunkers therefore the formula must be divided by 2 to obtain the length of each of them; thus we obtain the following

$$\textit{Formula.}\quad \text{Length} = \frac{\text{tons}\times45}{\text{width}\times\text{height}\times2}$$

Hence, by substitution, we have

Divide by 5
5

$$\text{Length} = \frac{\overset{13}{65}\times\overset{9}{45}}{\underset{1\cdot1}{5\cdot5}\times\underset{3\cdot1}{15\cdot5}\times2} = \frac{13\times9}{1\cdot1\times3\cdot1\times2}$$

$$\begin{array}{r} 3.1 \\ 1\cdot1 \\ \hline 3\cdot41 \\ 2 \\ \hline 6\cdot82 \\ \hline \end{array} \qquad \begin{array}{r} 13 \\ 9 \\ \hline 117 \\ \hline \end{array} \qquad \begin{array}{l} 6\cdot82)117\cdot00(17\cdot1554 \\ \quad\;\; 682 \\ \quad\;\; \overline{4880} \\ \quad\;\; 4774 \\ \quad\;\; \overline{\;1060} \\ \quad\;\;\;\; 682 \\ \quad\;\;\;\; \overline{3780} \\ \quad\;\;\;\; 3410 \\ \quad\;\;\;\;\; \overline{3700} \\ \quad\;\;\;\;\; 3410 \\ \quad\;\;\;\;\; \overline{2900} \\ \quad\;\;\;\;\; 2728 \\ \quad\;\;\;\;\; \overline{} \end{array} \qquad \begin{array}{r} 12 \\ \hline 1\cdot8648 \\ \hline \end{array}$$

Answer 17 feet 1·86 inches.

(11.) If one lb. steam raise the tempature of 1,000 lbs. of water 1°, and the sea water is 66°, and the discharge water is 110°; how many lbs. of circulating water passes the condenser for each lb. of steam?

RULE.

$$\text{lbs. of water passing condenser} = \frac{\text{lbs. of water raised } 1^\circ \text{ in temperature}}{\text{heat of discharge water} - \text{heat of sea water}}$$

$$\begin{array}{lr} \text{Discharge water......} & 110^\circ \\ \text{Sea water ....} & 66 \\ \hline \text{Temperature raised...} & 44 \\ \hline \end{array} \qquad 44\left\{\begin{array}{l} 11)\underline{1000} \\ \ \ 4)\ \ \underline{90\cdot909} \end{array}\right. $$

$$\text{Answer}\ \ \underline{22\cdot727}\ \text{lbs.}$$

(12.) The piston is 52" diameter, and at the beginning of the stroke the pressure is 36 lbs. per square inch; if the crank pin be 9" diameter; what length should it be in the bearing if the pressure on the oil is not to exceed 700 lbs. per square inch?

$$\textit{Formula.}\quad l = \frac{\cdot7854\ D^2\ p}{700\ d}$$

Where l = length
D = diameter of piston } in inches.
d = " crank pin
p = pressure; in lbs.

Hence, by substitution, we have

$$\text{Length} = \frac{\overset{\cdot1122}{\cancel{\cdot7854}}\times52\times52\times\overset{4}{\cancel{36}}}{\underset{100}{\cancel{700}}\times\underset{1}{\cancel{9}}} = \frac{\cdot1122\times52\times52\times4}{100}\quad \begin{array}{r}\text{Divide by } 7\\ 9\end{array}$$

$$\begin{array}{r} \cdot1122 \\ 52 \\ \hline 2244 \\ 5610 \\ \hline 5\cdot8344 \\ 52 \\ \hline 116688 \\ 291720 \\ \hline 303\cdot3888 \\ 4 \\ \hline 1{,}00)12{,}13\cdot5552 \\ \hline \end{array}$$

$$\text{Answer}\quad \underline{12\cdot1355}\quad \text{inches.}$$

PAPER II.

SECOND CLASS.

1. 514 times the 100 thousandth part of an inch.

$$\begin{array}{r} 514 \\ \cdot 00001 \\ \hline \cdot 00514 \\ \hline \end{array}$$

Remarks. ·1 = 1 tenth; ·01 = 1 hundreth; ·001 = 1 thousandth; and so on.

2. $(6'\ 4\frac{3}{4}'' - 4'\ 6\frac{7}{8}'') \times 12$.

$$\begin{array}{rr} 6 & 4\frac{6}{8} \\ 4 & 6\frac{7}{8} \\ \hline 1 & 9\frac{7}{8} \\ & 12 \\ \hline 21 & 10\frac{4}{8} \\ \hline \end{array} \text{ Answer.}$$

Remarks. In addition or subtraction of fractions they must be reduced to a common denominator, as follows

Since $\frac{7}{8}$ is greater than $\frac{6}{8}$ add 1 to $\frac{6}{8}$ and proceed as follows

$$\frac{6}{8}+1 = \frac{6}{8}+\frac{8}{8} = \frac{6+8}{8} = \frac{14}{8}$$

Then, take $\frac{7}{8}$ from $\frac{14}{8}$ thus; $\frac{14}{8} - \frac{7}{8} = \frac{14-7}{8} = \frac{7}{8}$

Next, because 1 is added to the fraction $\frac{6}{8}$, 1″ must be added to the 6″, thus making the inches to be subtracted 6″+1″ = 7″.

In multiplying the fractions, proceed as follows:

$$\frac{7}{8}\times 12 = \frac{7\times 12}{8} = \frac{84}{8} = 10+\frac{4}{8}$$

3. (36 — 16+9·4) (6 — 4)
6 — 4 = 2

Add {+36
+ 9·4
+45·4
Subtract —16
+29·4
Multiply by +2
+58·8 Answer.

4. (36 — 16+9·4) (4 — 6)
4 — 6 = — 2

+36
+ 9·4
+45·4
—16
+29·4
Multiply by — 2
—58·8 Answer.

5. (36 — 16+9·4)×(6 — 4)
6 — 4 = 2

+36
+ 9·4
+45·4
—16
+29·4
Multiply by +2
+58·8 Answer; which is the same as 3.

6. (36 — 16+9·4)×6 — 4

+36
+ 9·4
+45·4
—16
+29·4
6
+176·4
—4 0
+172·4 Answer.

Remarks. The student will observe the different answers to the questions when the signs are changed, or the brackets taken away.

7. A ship's mast head is 96 feet above the level of the sea when upright; but when she is heeling over under pressure of canvas, it is 84 feet above the sea; the valve is 6″ diameter, and loaded with a weight of 784 lbs. when the ship is upright; what will she blow off at when heeling over?

Expressing the formula Article 18, in words at length we have the following.

Formula

$$\text{Pressure per square in. when heeling} = \frac{\text{height of mast, when heeling} \times \text{weight of valve}}{\text{height of mast, when upright} \times (\text{diameter})^2 \times \cdot 7854}$$

Hence, by substitution, we have

Divide by 12
7

$$\text{Pressure} = \frac{\overset{\overset{1}{7}}{84} \times \overset{98}{784}}{\underset{\underset{1}{8}}{96} \times 6 \times 6 \times \underset{\cdot 1122}{\cdot 7854}} = \frac{98}{6 \times 6 \times \cdot 1122}$$

$$\begin{array}{rcl} \cdot 1122 & & \\ 36 & = & 6 \times 6 \\ \hline 6732 & & \\ 3366 & & \\ \hline 4\cdot 0392 & & \\ \hline \end{array}$$

$$\begin{array}{l} 4\cdot 0392)98\cdot 0000(24\cdot 26 \text{ lbs. Answer.} \\ 80784 \\ \overline{172160} \\ 161568 \\ \overline{105920} \\ 80784 \\ \overline{251360} \\ 242352 \\ \overline{} \end{array}$$

8. The speed of the ship is 8·5 knots per hour, and the consumption 11 tons per day; but the speed at another time is 9·2 knots per hour, and consumption 14 tons per day; what is the rate of cost per day?

Rule. $$\frac{C_{,}K - CK_{,}}{K_{,} - K}$$

Where $C_{,}$ = greater consumption
C = least ,,
$K_{,}$ = greater knots
K = least ,,

Hence by substitution, we have

$$\frac{14\times 8{\cdot}5 - 11\times 9{\cdot}2}{9{\cdot}2 - 8{\cdot}5}$$

9·2	14	11
8·5	8·5	9·2
·7	70	22
	112	99
	119·0	101·2
	101·2	
	·7) 17·8	
	25·4286 Answer.	

9. Verify the above formula by working at full length under the two conditions, for a voyage of 1300 miles, work to 4 decimals. To find the time expended and tons consumed at 8·5 knots.

	knots. knots. days.
8·5 knots in 1 hour	204)1300(6·3725
2 4 hours in 1 day	1224
340	760
170	612
204·0 knots in 1 day	1480
	1428
6·3725 days on voyage	520
11 tons per day	408
70·0975 tons on voyage	1120
	1020

To find the time expended and tons consumed at 9·2 knots.

	knots. knots. days.
9·2 knots in 1 hour	220·8)1300·0(5·8877
24 hours in 1 day	11040
368	19600
184	17664
220·8 knots in 1 day	19360
	17664
5.8877 days on voyage	16960
14 tons per day	15456
235508	15040
58877	15456
82·4278 tons on voyage	

To compare the days and tons expended.

6·3725	82·4278	·4848)12·3303(25·43 Answer.
5·8877	70·0975	9696
·4848	12·3303	26343
		24240
		21030
		19392
		16380
		14544

10. What is the boiler pressure when the diameter of $L\ P$ cylinder is 62", that of $H\ P$ cylinder 38", and that of crank shaft 9", and stroke 31'?

Formula. $$B = \frac{f\,d^3 - 15\,S\,D^2}{S\,H^2}$$

Where B = boiler pressure; in lbs.
f = 4936 for crank shaft, and 5760 for tunnel shaft
d = diameter of shaft
D = ,, L. P. cylinders
H = ,, H. P. ,,
S = length of stroke
} in inches

Hence, by substitution, we have

$$\text{pressure} = \frac{4936 \times 9^3 - 15 \times 31 \times 62^2}{31 \times 38^2}$$

H 38	9 d	f 4936	62 D
38	9	729	62
304	81 d^2	44424	124
114	9	9872	372
		34552	
H^2 1444	729 d^3		3844 D^2
S 31		3598344	31 S
		1787460	
1444			3844
4332		1810884	11532
$S\,H^2$ 44764			119164
			15
44764)1810884(40·45 lbs.			595820
179056			119164
203240			1787460
179056			
241840			
223820			

Answer 40·45 lbs.

11. A compound engine has a steam receiver round the H. P. cylinder, equal in diameter to the L. P. cylinder, steam chest for slides between the cylinders; distance between the centres of the cylinders 82", diameter of L. P. cylinder 48", and depth 58"; how many square feet of felting will be required to cover it?

In the diagram No. 4 let $A\ B\ C\ D\ E\ F$ be the upper edge of the external part of the objects around which the felting goes, and $G\ L$ a vertical section through $M\ N$ the centres of the cylinders.

Then, the two semicircles are equal to a circle, and $AF + CD = 2\ MN$

$$\text{Hence } a = (3{\cdot}1416d + MN \times 2)\ b$$

Where a = area of felting
d = diameter of L. P. cylinder
$M N$ = distance between centres of cylinders
$G K = b$ = breadth, or depth of felting

Hence, by substitution, we have

$$\text{area} = (3{\cdot}1416 \times 48 + 82 \times 2) \times 58$$

$$\begin{array}{rrl}
 & 3{\cdot}1416 & 28 \\
 & 48 & 2 \\ \cline{2-3}
 & 251328 & 164 \\
 & 125664 & \\ \cline{2-2}
 & 150{\cdot}7968 & \\
 & 164\phantom{{\cdot}7968} & \\ \cline{2-2}
 & 314{\cdot}7968 & \\
 & 58 & \\ \cline{2-2}
 & 25183744 & \\
 & 15739840 & \\ \cline{2-2}
 & 18258{\cdot}2144 & \text{square inches.} \\
144\left\{\begin{array}{l} 12) \\ \\ 12) \end{array}\right. & \begin{array}{r} 1521{\cdot}5179 \\ \hline 126{\cdot}7981 \end{array} & \begin{array}{l} \\ \\ \text{square feet.} \end{array} \\ \cline{2-2}
\end{array}$$

12. A bonus of £72 is to be divided among 3 engineers, in proportion to the amount of wages they have received; A's wages are £102, B's wages are £75, and C's wages £57; what part of the £72 will each man receive?

A's wages 102
B's do. 75
C's do. 57
234

234 : 102 : : 72
72
204
714

234)7344(£31 7s. $8\frac{72}{234}$d.
702
324
234
90
20
234)1800(7s.
1638
162
12
234)1944(8d.
1872
72
234

	£	s.	d.		
A's share of bonus	31	7	$8\frac{72}{234}$	72	234
B's do.	23	1	$6\frac{108}{234}$	108	$\frac{234}{234} = 1$
C's do.	17	10	$9\frac{54}{234}$	54	
Sum of fractions	0	0	1		
Sum of shares =	72	0	0		

Note. B and C's shares are found in the same manner as A's.

PAPER III.

SECOND CLASS.

1. $$72 \div \left(\frac{5 \times 9 + 8 - 2}{6^2 - 33}\right) = 72 \div \left(\frac{45+6}{36-33}\right)$$

$$= 72 \div \frac{51}{3} = \frac{72}{17} = 4{\cdot}235 \text{ Answer.}$$

2. 3 cwt. 2 qrs. 27 lbs. tallows at 54s. per cwt. Answer £10 $2\frac{1}{30}$s.

3. What is the weight of gunmetal in a screw shaft liner, length 46 inches, outer diameter of liner 13 inches, thickness of liner ¾ inch; if a cubic inch weigh ·3 of a lb.?

The liner is a hollow cylinder; hence, by Article 11 formula A we obtain its volume in cubic inches, which being multiplied by the weight of a cubic inch we thus obtain the following *formula*:

$$\text{Weight} = {\cdot}7854\,(D^2 - d^2) \times \text{length} \times {\cdot}3$$

Where D = outer diameter of liner

d = inner do.

$$D = 13'' \quad \therefore \text{Weight} = {\cdot}7854 \times (13^2 - 11{\cdot}5^2) \times 46 \times {\cdot}3$$

$$\tfrac{3}{4} \times 2 = 1\tfrac{1}{2}$$

$$d = 11\tfrac{1}{2}$$

13	11·5	36·75	28·86345
13	11·5	·7854	46
39	575	14700	17318070
13	1265	18375	11545380
		29400	
169	132·25	25725	1327·71870
132·25			·3
		28·863450	
36·75			398·31561

Answer 398·31561 lbs.

4. An oil tank is 3′ 6″ long, 2′ 9″ broad, and 1′ 10″ high; what was the consumption per day in gallons, if in 5 days the oil be lowered 4 inches in the glass?

In this question the height of the tank has nothing to do with its solution, and the height of the oil may be expressed as the fraction of a foot by dividing it by 12.

Hence, by Article 9 Formula A, and observing that there are 6¼ gallons in 1 cubic foot, we obtain the following

Formula

$$\text{Gallons consumed per day} = \frac{\text{length} \times \text{breadth} \times \text{depth} \times 6{\cdot}25}{\text{number of days}}$$

And, by substitution, we have

$$\text{gallons per day} = \frac{\overset{\cdot 7}{3{\cdot}5} \times 2{\cdot}75 \times \overset{1}{4} \times 6{\cdot}25}{\underset{1}{5} \times \underset{3}{12}} \qquad \begin{matrix}\text{Divide by } 5\\ 4\end{matrix}$$

$$= \frac{\cdot 7 \times 2{\cdot}75 \times 6{\cdot}25}{3} = 4{\cdot}0104$$

Auswer 4·0104 gallons per day.

5. 16′ 2¼″ × 6′ 3½″; find the product in square feet and decimals of a square foot.

$$\frac{1{\cdot}0}{4} = \cdot 25 \therefore 2\tfrac{1}{4}'' = 2''{\cdot}25\,; \quad \frac{2{\cdot}25}{12} = \cdot 1875.$$

$$\frac{1{\cdot}0}{2} = \cdot 5 \therefore 3\tfrac{1}{2}'' = 3{\cdot}5\,; \quad \frac{3{\cdot}5}{12} = \cdot 29167.$$

$$\therefore 16'\ 2\tfrac{1}{4}' \times 6'\ 3\tfrac{1}{2}' = 16'{\cdot}1875 \times 6'{\cdot}2917 = 101{\cdot}84689375.$$

Answer 101,84689375.

Remark. The sign ∴ is put for the word *therefore.*

6. A waste steam pipe of a spring loaded safety valve is 30 feet high; what extra pressure per square inch is on the valve should the pipe become filled with water?

$$\textit{Formula.} \quad \frac{h}{2{\cdot}305} = \frac{30}{2{\cdot}305} = 13{\cdot}02 \text{ lbs. Answer.}$$

Where h = height of pipe, in feet.

Note. A column of water 1 inch in area and 2·305 feet high weighs 1 lb.

7. What is the amount of wages

	£	s.	
From 18th April to 17th December at	15	0	per month.
17th June to 14th November	8	0	,,
21st June to 15th October	6	0	,,
22nd June to 15th ,,	4	10	,,

Note. Allow 30 days to the month.

Remarks. From the 18th of April to the 17th of December there are 243 days.

	days		days		£		£ s		
Then.	As 30	:	243	: :	15	:	121 10	=	First man's wages
	2		1		1				

2)243

121·5
20

10·0

Proceed in like manner, and then find the sum of all the wages. It is £201 19s.

8. What will be the N. H. P. of a cylinder whose diameter is 36", length of stroke 1′ 8″, and making 110 revolutions per minute ?

Formula.

$$\text{N.H.P.} = \frac{D^2 V}{6000} = \frac{D^2 s \times 2\,r}{6000}$$

Where D = diameter of cylinder; in inches.
V = velocity of stroke = $s \times 2r$.
s = length of stroke; in feet.
r = revolutions per minute.

Hence, by substitution and cancelling, we have

$$\text{N.H.P.} = \frac{36 \times 36 \times \frac{40}{12} \times 110}{6000} = \frac{36 \times 11}{5} = 79{\cdot}2$$

$$\text{Stroke} = 1'\ 8''$$
$$\times 2$$
$$\text{Stroke} \times 2 = 3'\ 4'' = \frac{40'}{12}$$

Answer 79·2 N. H.P.

9. A coal bunker is 7′ 3″ at the top and 5′ 9″ at the bottom, 21′ 6″ long, and 9′ 6″ high; how many tons of coals will it contain ; and how many cubic feet will you allow to a ton ?

Allow 45 cubic feet to 1 ton.

Formula

$$\text{Tons} = \frac{\text{length} \times \text{mean breadth} \times \text{height}}{45} = \frac{21{\cdot}5 \times 6{\cdot}5 \times 9{\cdot}5}{45}$$

$$\text{By cancelling} = \frac{4{\cdot}3 \times 6{\cdot}5 \times 9{\cdot}5}{9} = 29{\cdot}5028 \text{ tons Answer.}$$

7′ 3″ top
5 9 bottom
2)13 0
6 6 mean breadth

10. The rectangular bars for combustion chamber crown are 5·5″ × ¾″; 24″ apart, length of bars 36″; what pressure will be allowed in the boiler if there be 8 stays?

$$\text{Formula B} = \frac{72000\, d^2 t}{D\, L^2}$$

Where B = boiler pressure; in lbs.
D = distance apart of bars.
L = length of bars.
d = depth „
t = thickness, or width.

$$\text{Boiler pressure} = \frac{72000 \times 5{\cdot}5 \times 5{\cdot}5 \times 3}{24 \times 36 \times 36 \times 4}$$

Divide by 36
3
8

$$\text{By cancelling} = \frac{250 \times 5{\cdot}5 \times 5{\cdot}5}{36 \times 4} = 52{\cdot}52 \text{ lbs. Answer.}$$

11. What would the pressure be if there were 4 stays?

$$\text{Increase} = \frac{B}{N(N+2)} \quad \text{where } N = \text{number of stays}$$

$$= \frac{52{\cdot}52}{4 \times 6}$$

	lbs.
B	52·52
Increase	2·19
	54·71 Answer.

12. Find the collapsing pressure on a furnace tube whose thickness of plate is 7/16″ diameter 3′ 1″ and length 10′ 6″.

$$\text{Formula } p = \frac{t^2\ 806800}{l\ d}$$

Where p = pressure; in lbs.
t = thickness of plate } in inches.
d = diameter of tube } in inches.
l = length; in feet.

$$\text{Pressure} = \frac{7 \times 7 \times 806800}{16 \times 16 \times 10{\cdot}5 \times 87} = \frac{7 \times 40815}{16 \times 4 \times {\cdot}8 \times 87}$$

Divide by 4
5
7

$$\frac{6{\cdot}0}{12} = {\cdot}5 \quad \therefore \quad 10' \ 6'' = 10{\cdot}5'$$

Answer 897·25 lbs.

$$\begin{array}{l} 8' \ 1'' \\ 12 \\ \hline 87'' \\ \hline \end{array}$$

PAPER IV.

SECOND CLASS.

1. $70 \times 8 - 47 + 43$ Answer 556

2. $70 \times 8 - {\cdot}47 + {\cdot}43$ Answer 559·96

3. A tank is 32′ long, 19′ 6″ broad, and 6′ 8″ high; how long will it take to pump it out, the diameter of the pump being 7½″, stroke 10″, revolutions per minute 72, double acting, if 10 per cent. be non-effective?

From Article 15 Formula C we have the following *Formula.*

$$\text{Time} = \frac{\text{length} \times \text{breadth} \times \text{height} \times 1728}{{\cdot}7854 \times (\text{diameter})^2 \times \text{stroke} \times \text{revolutions} \times 2 \times 60 \times \text{fraction}}$$

$$\text{Fraction} = \frac{100 - 10}{100} = \frac{90}{100} = \frac{9}{10}$$

Hence, by substitution in the formula, and cancelling, we have

$$\text{Time} = \frac{32 \times 19{\cdot}5 \times 6{\cdot}25 \times 1728 \times 10}{{\cdot}7854 \times 7{\cdot}5 \times 7{\cdot}5 \times 10 \times 72 \times 2 \times 60 \times 9}$$

or

$$\text{Time} = \frac{32 \times 3{\cdot}9 \times {\cdot}05}{{\cdot}7854 \times 1{\cdot}5 \times {\cdot}3 \times 9} = 1{\cdot}9617 \text{ hours.}$$

Divide by 12
12
6
2
10
5
5
5
5

Answer 1 hour 57·702 minutes.

Note. To multiply by $\frac{10}{9}$ is equivalent to divide by $\frac{9}{10}$.

4. The piston is 52″ diameter, steam 28 lbs. per square inch, length of crank 18″, diameter of shaft 10½″; what is the strain per square inch? and is the shaft strong enough?

$$\text{Formula } S = \frac{5{\cdot}1\, W a}{d^3} = \frac{5{\cdot}1 \times {\cdot}7854\, D^2 s\, l}{d^3}$$

Where S = strain per square inch section of shaft, in lbs.
W = weight at leverage = $\cdot 7854\, D^2\, s$.
$a = l$ = length of lever
D = diameter of cylinder
d = „ shaft
(in inches.)
s = steam per square inch; in lbs.

$$\text{Strain} = \frac{5\cdot 1 \times \cdot 7854 \times 52 \times 52 \times 28 \times 18}{10\cdot 5 \times 10\cdot 5 \times 10\cdot 5}$$

$$= 4715\cdot 529 \text{ lbs. Answer.}$$

Which is less than the Board of Trade requirements; namely that the strain shall not exceed 5000 lbs. per square inch; therefore the shaft is strong enough.

5. What boiler pressure should be allowed for a shaft 12" diameter, cylinder diameter 60" and length of stroke 36"?

$$\textit{Formula } B = \frac{2880\, d^3}{D^2\, S}$$

Where B = boiler pressure; in lbs.
d = diameter of shaft
D = „ cylinder
S = length of stroke
(in inches.)

Cancel; divide by 12, 12, 12, 5, 3

$$\text{Pressure} = \frac{2880 \times 12 \times 12 \times 12}{60 \times 60 \times 36} = \frac{192}{5}$$

Answer 38·4 lbs.

6. An engine makes 48 revolutions per minute when the steam pressure is at 36 lbs.; it is reduced to 42 revolutions; what is now the pressure?

$$\textit{Formula } \frac{p}{P} = \frac{r^2}{R^2} \therefore p = \frac{P\, r^2}{R^2}$$

Where p = smaller pressure.
P = greater pressure.
r = smaller revolutions.
R = greater revolutions.

$$p = \frac{P\, r^2}{R^2} = \frac{36 \times 1764}{2304} = \frac{441}{16}$$

Answer 27·56.

7. The sea water is 72°, the water in the hot well is 124°; what will be the temperature of the hot well if the sea water be raised to 78° and you cannot use any more injection water?

$$\begin{array}{lr} \text{Sea water} & 78^\circ \\ \text{do.} & 72 \\ \hline \text{Difference} & 6 \\ \hline \end{array} \qquad \begin{array}{rrl} \text{Hot well} & 124^\circ & \\ \text{Add difference} & 6 & \\ \hline & 130 & \text{Answer.} \\ \hline \end{array}$$

8. On starting on a voyage the consumption is 12 tons per day, the temperature of the funnel is 548°, but at the end of the voyage it is 762°; what was the cause of this, and what was the consumption?

Note. Increase $= \dfrac{F}{2200} = \dfrac{t\,c}{2200}$

Where t = difference of temperatures.
c = coal in tons per day.

$$\begin{array}{rl} 762^\circ & \text{end} \\ 548 & \text{beginning} \\ \hline 214 & \text{difference} \\ \hline \end{array} \qquad \begin{array}{rrl} & 214 & \text{difference} \\ & 12 & \text{tons per day at first.} \\ \hline 2200\left\{\begin{array}{r} 11{,}00)\\ \\ 2) \end{array}\right. & \begin{array}{r} 25{,}68 \\ \hline 2{\cdot}334 \end{array} & \\ \hline & 1{\cdot}167 & \text{tons increase} \\ & 12{\cdot}000 & \text{tons original} \\ \hline \text{Answer} & 13{\cdot}167 & \text{tons consumption.} \\ \hline \end{array}$$

Cause of increase, soot and dirt in the tubes and funnel.

9. If the bolts in a cylinder cover be $1\frac{7}{16}$ diameter, and the diameter of cylinder 32″, pressure 44 lbs. per square inch; how many bolts will be required if the strain per square inch of their section is not to exceed 2100 lbs.?

From Article 19 Formula A we have the following *Formula.*

$$\text{Number of bolts} = \frac{(\text{diameter of cover})^2 \times \text{pressure}}{(\text{diameter of bolts})^2 \times \text{strain}}$$

Hence, by substitution, we have

$$\text{Bolts} = \frac{32 \times 32 \times 44}{\frac{23}{16} \times \frac{23}{16} \times 2100} = \frac{16 \times 16 \times 32 \times 32 \times 44}{23 \times 23 \times 2100} =$$

$$\frac{4 \times 16 \times 32 \times 32 \times 44}{23 \times 23 \times 525} \qquad 1\frac{7}{16} = \frac{23}{16}$$

Answer 10·38 bolts.

10. The I. H. P. of an engine is 696 and it uses 21 lbs. weight of steam per hour per I. H. P. If 1 lb. of steam on being condensed gives out sufficient heat to raise 1000 lbs. of water 1° Fahrenheit, and if the injection water has a temperature of 58° and the discharge water 108°; how many tons of injection water are used per day of 10 hours ?

From Article 20 formula A we obtain the following *Formula*

$$\text{Tons per day} = \frac{\text{horse power} \times \text{lbs. of steam per H.P.} \times 1000 \times 10}{2240 \times \text{difference of temperature}}$$

$$\text{Hence, Tons} = \frac{696 \times 21 \times 1000 \times 10}{2240 \times 50} \qquad \text{Divide by } \begin{array}{r} 50 \\ 20 \\ 8 \\ 2 \\ 7 \end{array}$$

$$\text{By cancelling} = 87 \times 3 \times 5 = 1305 \text{ tons Answer}$$

11. If the diameter of the barrel of a wheel and axle be 9", and the diameter of the rope 1¼", and the weight 242 lbs; what force must be applied to the handle whose length is 20" ?

From Article 21 formula B we have the following *Formula*

$$\text{Force applied} = \frac{\text{weight} \times \tfrac{1}{2} \text{ (diameter of barrel} + \text{diameter of rope)}}{\text{length of handle}}$$

$$\begin{array}{l} \text{Barrel } 9'' \\ \text{Rope } \ \ 1\tfrac{1}{4} \\ \hline 2)10\tfrac{1}{4} \\ \hline \ \ \ 5\tfrac{1}{8} = \dfrac{41}{8} \\ \hline \end{array}$$

Hence, by substitution, we have

$$\text{Force} = \frac{242 \times 41}{20 \times 8} = 62{\cdot}0125 \text{ lbs. Answer.}$$

12. If the sea water be at 64° Fahrenheit, and the water in the hot well at 106°; how many lbs will be required to condense 1 lb. of steam ?

$$\text{Rule.} \qquad \frac{1149{\cdot}6^\circ - t'}{t' - t}$$

Where t = temperature of sea water
t' = ,, hot well

$$\frac{1149{\cdot}6^\circ - 106^\circ}{106^\circ - 64^\circ} = \frac{1043{\cdot}6^\circ}{42^\circ} = 24{\cdot}85 \text{ lbs. Answer.}$$

13. If the piston be 34″ diameter, and assuming it to be 2″ thick throughout; what should it weigh if 3·9 cubic inches of cast iron weigh 1 lb?

From Article 10 formula A divided by the weight of 1 cubic inch we obtain the following *Formula.*

$$\text{Weight} = \frac{\cdot 7854 \times (\text{diameter})^2 \times \text{thickness}}{3\cdot 9}$$

Hence, by substitution, we have

$$\text{Weight} = \frac{\cdot 7854 \times 34^2 \times 2}{3\cdot 9} = 465\cdot 601 \text{ lbs.}$$

Answer 4 cwt 0 qrs. 17·6 lbs.

14. A sheet of lead 14′ 6″ long, 11′ 9″ broad, and ⅜″ thick; what will it cost at 3¾d. per lb., if a cubic inch weigh ·4126 of a lb?

$$\begin{array}{ll} 14' \; 6'' & \qquad 11' \; 9'' \\ \underline{12} & \qquad \underline{12} \\ 174 \text{ inches} & \qquad 141 \text{ inches.} \end{array}$$

$$\begin{array}{lcll} \text{Volume} & = & l\,b\,t = 174 \times 141 \times \tfrac{3}{8} & = 9200\cdot 25 \text{ cubic inches.} \\ \text{Weight} & = & 9200\cdot 25 \times \cdot 4126 & = 3796\cdot 023 \text{ lbs.} \\ \text{Cost} & = & 3796\cdot 023 \times 3\tfrac{3}{4} & = 59 \;\; 6 \;\; 3\cdot 09 \end{array}$$

Answer £59 6s. 3·09d.

Note. $l\,b\,t$ = length × breadth × thickness.

PAPER V.

SECOND CLASS.

1. $324 \div 4 + 49 - 28 \times 4$ Answer 18.

2. $\dfrac{9^5 - (16 - 4)^2}{4^3}$ Answer 920·390625.

3. Add together 5′ 4½″, 18′ 9¾″, 7′ 5⅞″ and 14′ 9$\frac{11}{16}$″

Reduce the fractions to equivalent fractions with a common denominator, add the new numerators together and divide their sum by the common denominator, add the quotient to the feet and inches; as follows

$$\frac{1}{2} = \frac{1\times 8}{2\times 8} = \frac{8}{16};\ \frac{3}{4} = \frac{3\times 4}{4\times 4} = \frac{12}{16};\ \frac{7}{8} = \frac{7\times 2}{8\times 2} = \frac{14}{16}$$

$$\begin{array}{r} 8 \\ 12 \\ 14 \\ 11 \\ \hline 16)45(2 \\ 32 \\ \hline 13 \\ \hline 16 \end{array} \qquad \begin{array}{rl} 5 & 4 \\ 18 & 9 \\ 7 & 5 \\ 14 & 9 \\ & 2\frac{13}{16} \\ \hline 46 & 5\frac{13}{16} \text{ Answer.} \\ \hline \end{array} \qquad \begin{array}{r} 12)29 \\ \hline 2\ 5 \\ \hline \end{array}$$

4. The travel of the slide is 3·5″, cover 3″ lead ⅛″, and stroke of the piston 58″; how far is the piston from the end of the stroke when the steam is cut off?

Formula $S = \left(\dfrac{2c+l}{t}\right)^2 s$

Where S = distance from end of stroke when steam is cut off.
c = cover.
l = lead.
t = travel of slide.
s = stroke of piston.

$$\text{Piston from end} = \left(\frac{2\times 3+\frac{1}{8}}{8\cdot 5}\right)^2 \times 58 = \left(\frac{6\cdot 125}{8\cdot 5}\right)^2 \times 58 =$$

$$\frac{1\cdot 0}{8} = \cdot 125 \qquad (\cdot 7206)^2 \times 58 = 30\cdot 11733 \text{ in. Ans.}$$

5. What is the cost of wrought iron forging, weighing 6 cwts. 2 qrs. 18 lbs. at 26s 9d. per cwt? Answer £8 16s. $11\frac{84}{112}$d.

6. When the temperature of the hot well was 118° Fahrenheit, the evaporation was 7·4 lbs. of water for 1 lb. of coals; what will the evaporation be if the temperature of the hot well is increased to 165°?

$$\text{Increase} = \frac{F}{1100}\text{; where } F = \text{difference of temperatures} \times \text{by original evaporation.}$$

```
 165°
 118  subtract              11,00)3,47·8
 ───                              ─────
  47                               ·316 Increase
  7·4 multiply                     7·4  Original evaporation
 ───                              ─────
 188                        Answer 7·716 lbs. New evaporation
 329                               ─────
────
 347·8 = F
────
```

7. The diameter of the cylinder is 6′ 8″, length of stroke 6′ 6″, revolutions per minute 17, and the pressure of steam per square inch 14 lbs.; what is the horse power?

By Article 17 Formula G we have the following *Formula.*

$$\text{Horse power} = \cdot0000238 \times (\text{diameter})^2 \text{ in inches} \times \text{pressure} \times \text{stroke, in feet} \times \text{revolutions} \times 2$$

Note. $\cdot7854 \div 33000 = \cdot0000238.$

```
Diameter 6′ 8″
           12
         ───
In inches 75
         ───
```

Hence, by substitution in the formula we have

$$
\begin{aligned}
H.\,P. &= \cdot0000238 \times 75^2 \times 14 \times 6\cdot5 \times 17 \times 2 \\
&= 414\cdot20925 \text{ Answer.}
\end{aligned}
$$

8. A coal bunker is 17′ 6′ wide by 10′ 11″ high, and in 6 days a section of the bunker 12′ long was consumed; what was the consumption per day?

By Article 9 formula A we obtain the cubic feet in the tank; which being divided by the cubic feet in 1 ton, and by the number of days, gives the following. Allow 45 cubic feet to 1 ton.

Formula

$$\text{Consumption per day} = \frac{\text{width} \times \text{height} \times \text{length}}{\text{cubic feet in 1 ton} \times \text{days}}$$

$$\frac{6{\cdot}0}{12} = {\cdot}5 \qquad = \frac{17{\cdot}5 \times 131 \times 12}{45 \times 12 \times 6} = \frac{3{\cdot}5 \times 131}{9 \times 6} = \overset{\text{Divide by 12}}{\overset{5}{8{\cdot}49074}}$$

$$\begin{array}{r} 10\tfrac{11}{12} \\ 12 \\ \hline 131 \\ \hline 12 \end{array}$$

Answer 8·49074 tons.

Note. 11 inches may be expressed as a fraction of a foot, thus $\frac{11}{12}$; and $10\frac{11}{12}$′ may be then reduced to an improper fraction, and by being so the question will be put in a simpler form than by expressing 10.′ 11″ in the form of a decimal fraction.

9. An air pump is 13½″ diameter, and 16 inch stroke; the cylinder is 28″ diameter, and 29″ stroke; is the air pump large enough? Should air pumps be larger or smaller for surface condensers?

By Article 10 formula A, and observing that h is the length of the stroke, we obtain the following *Formulæ*

$$\text{Volume of pump} = {\cdot}7854 \times \text{diameter}^2 \times \text{stroke} = {\cdot}7854 \times 13{\cdot}5^2 \times 16$$
$$= 2290{\cdot}226.$$

$$\frac{\textit{Volume of Cylinder}}{8} = \frac{{\cdot}7854 \times \textit{diameter}^2 \times \textit{stroke}}{8} = \frac{{\cdot}7854 \times 28^2 \times 29}{8}$$
$$= 2232{\cdot}107$$

The Board of Trade allow ⅛ of the capacity of the cylinder for the capacity of the air pump; hence, in this question, the air pump is large enough.

Air pumps should be smaller for surface condensers, because they have only the condensed steam to take away.

10. In a wheel and axle, the diameter of the barrel was 7″ and of the rope 1⅛″; the crank handle was 15″ long and the weight was 214 lbs.; what was the force exerted allowing 15 per cent. for friction?

From formula B Article 21 we obtain the following *Formula*,

$$\text{Force} = \frac{\text{weight} \times \text{half (diameter of barrel} + \text{diameter of rope)}}{\text{length of handle}}$$

$$= \frac{214 \times 4{\cdot}0625}{15} = \frac{214 \times {\cdot}8125}{3} = 57{\cdot}9583$$

$$\begin{array}{rl} \text{Barrel} & 7'' \\ \text{Rope} & 1\tfrac{1}{8} \\ \hline 2)\!\!\!\! & 8\tfrac{1}{8} \\ \hline & 4\tfrac{1}{16} = 4{\cdot}0625 \\ \hline \end{array} \qquad \begin{array}{r} 57{\cdot}9583 \\ 15 \\ \hline 2897915 \\ 579583 \\ \hline 100)8{,}69{\cdot}3745 \\ \hline 8{\cdot}694 \\ \hline \end{array}$$

$$16\left\{\begin{array}{l}4)\,1{\cdot}0\\ \hline 4)\ {\cdot}25\\ \hline \quad{\cdot}0625\end{array}\right.$$

	lbs.
Force without friction	57·958
15 per cent friction	8·694
Force with friction	66·652 Answer.

11. Sketch a slide valve worked by a hooped spindle, the hoop surrounding the body of the valve. The port of the valve is 18″ wide, exhaus port is $5\frac{1}{2}''$ deep, steam ports $2\frac{1}{2}''$ deep, bars $1\frac{1}{2}''$, steam lap 3″ interna cover $\frac{1}{16}$, the valve is $1\frac{1}{4}''$ on each side of the ports, face of valve is 1 thick, while the rest is $\frac{3}{4}''$ thick, the port of the valve is rectangular, and 4″ deep. Find the weight; allowing 3·9 cubic inches of cast iron to weigh 1 lb?

In the figure No. 8 let

$M\,N$; represent the whole width of the *valve*.
$M\,P = Q\,N$; the width of the *valve faces*.
$P\,Q$; the *valve port*.
E; the *exhaust port*.
B, B; the *bars*, or *bridges*.
S, S; the *steam ports*.
L, L; the *steam lap*.

The valve is represented at *half stroke*, the parts of the valve faces outside of the steam ports are called *outside lap*, or *outside cover*, or *steam lap*; and the parts of the faces, inside of the steam ports are called *inside lap*, or *inside cover*. If the face of the valve do not entirely cover the steam ports, the part left uncovered is called *inside clearance*.

To find the breadth of the valve port $= P\,Q$

$$\begin{aligned}P\,Q &= M\,N - (M\,P + Q\,N) = M\,N - M\,P \times 2\\ M\,N &= (\text{steam lap} + \text{steam port} + \text{bar}) \times 2 + \text{exhaust port}\\ &= (3 + 2\tfrac{1}{2} + 1\tfrac{1}{2}) \times 2 + 5\tfrac{1}{2} = 7 \times 2 + 5\tfrac{1}{2} = 19\tfrac{1}{2}\\ M\,P \times 2 &= (\text{steam lap} + \text{steam port} + \text{internal cover}) \times 2\\ &= (3 + 2\tfrac{1}{2} + \tfrac{1}{16}) \times 2 = (3 + 2\tfrac{8}{16} + \tfrac{1}{16}) \times 2 = 5\tfrac{9}{16} \times 2 = 11\tfrac{1}{8}\end{aligned}$$

$$\frac{1{\cdot}0}{2} = {\cdot}5 \qquad M\,N. = 19{\cdot}5$$

$$M\,P \times 2 = 11{\cdot}125$$

$$\frac{1{\cdot}0}{8} = {\cdot}125 \qquad P\,Q = 8{\cdot}375 \text{ breadth of valve port}$$

FACE.

TO FIND THE CUBIC INCHES IN THE ENDS OF THE FACE.

For the length for calculation, we have the width of the valve port + the distance on each side of the port $= 18'' + 1\frac{1}{4}'' + 1\frac{1}{4} = 20\frac{1}{2}$

For the breadth for calculation, we have twice $M\,P = 11\frac{1}{8}''$

And the thickness is 1".

Hence ; cubic inches = 20·5×11·125×1

11·125 breadth
20·5 length

55625
222500

228·0625
1 thickness

228·0625 cubic inches in ends of face.

TO FIND THE CUBIC INCHES IN THE SIDES OF THE FACE.

To find the length for calculation we have *P Q* = the breadth of the valve port = 8·375.

For the breadth for calculation we have the distance on each side of the port = 1¼+1¼ = 2½.

And the thickness is 1".

Hence ; cubic inches = 8·375×2·5×1

8·375 length
2·5 breadth

41875
16750

20·9375
1 thickness

20·9375 cubic inches.

RECESS.

TO FIND THE CUBIC INCHES IN THE WALLS.

The length of each of the side walls for calculation is equal to the width of the valve port + twice the thickness of the wall = 18"+¾"+¾ = 19½" = 19·5.

The length of each of the end walls is = the breadth of the valve port = 8·375.

Hence the length of all the walls

= (19·5+8·375)×2 = 55·75.

The breadth of the wall for calculation is found from the depth of the recess + the thickness of the back — the thickness of the face = 4"+¾" —1" = 3¾" = 3·75.

And the thickness is ¾" = ·75.

Hence; cubic inches = 55·75 × 3·75 × ·75

55·75 length	209·0625
3·75 breadth	·75 thickness
27875	10453125
39025	14634375
16725	156·796875 cubic inches.
209·0625	

TO FIND THE CUBIC INCHES IN THE BACK.

For the length and breadth for calculation we have the width and beadth of the valve port, and the thickness is ¾".

Hence; cubic inches = 18 × 8·375 × ·75.

8·375 breadth	150·75
18 length	·75 thickness
67000	75375
8375	105525
150·750	113·0625 cubic inches.

Ends of face	228·0625
Sides ,,	20·9375
Walls	156·7969
Back	113·0625
Cubic inches	518·8594

3·9)518·8594)133·041 lbs. Answer.
39

128
117

118
117

159
156

34
39

5

PAPER VI.

1. Express in figures, seven millions, five hundred and sixty thousands and fourteen. Answer 7 560 014.

2. Add together 10 tons 2 qrs. 17 lbs.; and 15 tons 8 cwts. 3 qrs. 28 lbs., and multiply the sum by 9.

Answer 227 tons 1 cwt. 1 qr. 24 lbs.

3. What is the product of $9{\cdot}72 \times {\cdot}14 \times {\cdot}004$

Answer ·0054432.

4. Divide the product of (3) by 9. Answer ·0006048.

5. The quantity of coals on board on leaving port is 417 tons; the consumption in 14 days is 210 tons 15 cwts. 2 qr. 14 lbs.; what quantity remains on board? Answer 206 tons 4 cwts. 1 qr. 14 lbs.

6. A coal bunker is 15 feet 6 inches long, 9 feet 3 inches high, and 5 feet 9 inches wide; required the quantity of coals it will contain at 45 cubic feet per ton? (By decimals).

By dividing formula A Article 9 by the cubic feet in 1 ton we obtain the following

$$\textit{Formula.}\quad \text{Tons} = \frac{\text{length} \times \text{height} \times \text{width}}{\text{cubic feet in 1 ton}} = \frac{15{\cdot}5 \times 9{\cdot}25 \times 5{\cdot}75}{45}$$

Answer 18 tons 6 cwts. 1 qr. 17·11 lbs.

7. The consumption of coal is 11 tons per day to produce a speed of 8½ knots per hour; what is the consumption on a voyage of 1240 knots?

Answer 66 tons 17 cwts. 1 qr. 0·56 lbs.

$$\begin{array}{lcccccc} & \text{knots.} & & \text{knots.} & & \text{tons.} & & \text{tons.} \\ \text{As} & 8{\cdot}5 \times 24 & : & 1240 & :: & 11 & : & 66{\cdot}8627. \end{array}$$

8. If the pressure of steam on the piston be 52 lbs. per square inch above the atmosphere, and the barometer on the condenser shews 27 inches of mercury; required the effective pressure per square inch on the piston? Answer 65·5 lbs.

$$\text{Effective pressure} = 52 + \frac{27}{2} = 65{\cdot}5.$$

9. What pressure of steam in the boiler will be necessary to blow off the brine through the blow off cocks, the bottom of the boiler being 15 feet below the water line of the ship, allowing a column of water 2·305 high to equal 1 lb ?

15 ÷ 2·305 = 6·5 lbs. Answer.

10. How many revolutions must an engine make to drive a paddle wheel 9½ knots per hour, the diameter of wheel being 18 feet, and the knot 6080 feet ?

Answer 1021·4 revolutions.

$$\text{Revolutions} = \frac{6080 \times \text{knots}}{3{\cdot}1416 \times \text{diameter}} = \frac{6080 \times 9{\cdot}5}{3{\cdot}1416 \times 18}$$

11. The pitch of the screw is 15 feet ; how many revolutions must it make to advance 8½ knots per hour, a knot being 6080 feet ?

Answer 3445·3 revolutions.

$$\text{Revolutions} = \frac{6080 \times \text{knots}}{\text{pitch}} = \frac{6080 \times 8{\cdot}5}{15}$$

12. A safety valve is loaded to 26 lbs. per square inch by a direct weight of 542 lbs.; how much would be required to be taken off to reduce the pressure to 19 lbs. per square inch ?

Answer 145·9 lbs.

$$\text{Weight taken off} = \left(\frac{\text{old pressure} - \text{new pressure}}{\text{old pressure}}\right) \times \text{old weight}$$

$$= \left(\frac{26-19}{26}\right) \times 542 = \frac{7}{26} \times 542.$$

13. To what height must a safety valve of 8½ inches diameter be lifted to allow a free escape of steam equal to the area of the valve ?

Answer 2·125 inches.

By Article 26 formula A we have the following

$$\text{Height lifted} = \frac{\text{diameter}}{4} = \frac{8{\cdot}5}{4}$$

14. How many cubic feet of water will be extracted in an hour by a brine pump 7 inches diameter, and 16 inches stroke, making 28 strokes per minute, the pump being $\frac{5}{7}$ full each stroke ?

From Article 13 formula A we obtain the following *Formula* :

$$\text{Cubic feet} = \frac{\cdot 7854 \times (\text{diameter})^2 \times \text{stroke} \times \text{number} \times \text{fraction} \times 60}{1728}$$

Divide by 12
6
8
7

$$= \frac{\cdot 7854 \times 7 \times 7 \times 16 \times 28 \times 5 \times 60}{1728 \times 7}$$

Answer 427·606 cubic feet.

15. What is the horse power of an engine, the diameter of cylinder being 5 feet 6 inches, the length of stroke 4 feet 8 inches, revolutions per minute 16, and effective pressure per square inch on the piston 24 lbs. ?

From Article 17 formula G we obtain the following *Formula*:

$$H\,P. = \cdot 0000238 \times (\text{diameter})^2 \text{inches}, \times 2 \times \text{stroke, feet}, \times \text{revolutions} \times \text{pressure}$$

$$= \cdot 0000238 \times 66^2 \times 8{\cdot}5 \times 16 \times 24$$

Answer 338·388 horse power

5′ 6″
12

66 diameter

4′ 8″
2

8 6 = 8·5′ stroke, in feet.

16. If a bar of iron 1 inch square be torn asunder by a strain of 4500 lbs.; what force will be required to break a bar 2½ inches square ?

Answer 28125 lbs.

$$\text{Force} = \text{inches square} \times 4500 = 2{\cdot}5 \times 2{\cdot}5 \times 4500$$

PAPER VII.

SECOND CLASS.

1. 549 792 542 319 Express this in words.

Answer. Five hundred and forty-nine thousand seven hundred and ninety-two millions, five hundred and forty-two thousand three hundred and nineteen.

Note. Divide the figures into groups of six figures, and subdivide those groups into other groups of three figures.

2. The bolts of a cylinder cover are to be placed not more than 2¼ inches apart, centre to centre on the circumference of the pitch circle, diameter of cover 28″, and the bolts 1 inch from the edge of the cover; how many bolts?

Answer 32·67 bolts.

$$\frac{(28-2)\times 3{\cdot}1416}{2{\cdot}5} = \frac{26\times 3{\cdot}1416}{2{\cdot}5}$$

3. A single-rivetted boiler has 7 courses of 6 plates in each course, and each plate has 34 by 16 holes; how many rivets?

Answer 2172 rivets.

Rule.

$$\begin{aligned}\text{Rivets} &= (\text{side holes} - 1)\times\text{plates}\times(\text{courses}+1)\\ &+ (\text{end holes} - 2)\times\text{plates}\times\text{courses}\\ &= (34-1)\times 6\times(7+1)+(16-2)\times 6\times 7\\ &= 33\times 6\times 8+14\times 6\times 7\end{aligned}$$

4. An engine counter stood at 1046 at the commencement of the voyage, and after 8 d. 9 h. 12 m. stood at 632541; how many revolutions per minute?

Answer 52·3 revolutions.

8 d. 9h. 12. = 12072 minutes. $\dfrac{632541-1046}{12072} = 52{\cdot}3$

5. A tank is 8 feet 6 inches by 2 feet 3 inches, and contains 900 gallons; what is its height?

By Article 9 Formula A.

$$v = l\,b\,h = \text{cubic feet} = \frac{\text{gallons in tank}}{\text{gallons in 1 cubic foot}}$$

$$\therefore\ h = \frac{\text{gallons in tank.}}{l\,b \times \text{gallons in 1 cubic foot}}$$

which expressed in words at length gives the *Formula* :

$$\text{Height} = \frac{\text{gallons in 1 tank}}{\text{length} \times \text{breadth} \times \text{gallons in 1 cubic foot}}$$

$$= \frac{900}{8{\cdot}5 \times 2{\cdot}25 \times 6{\cdot}25}$$

Answer 7 feet 6·35 inches.

6. What are the wages of 18 men, 18 days at 8s. 8d. per day
" " 14 " 12 " 7s. 5d. "
" " 10 " 15 " 6s. 7d. "

Answer £218 1s. 6d.

7. The consumption per day is 14½ tons of coal, the average H. P. indicated is 150; what is the consumption per hour per H. P. ?

$$\frac{2240 \times 14{\cdot}5}{24 \times 150} = 9{\cdot}022\ \text{lbs. Answer.}$$

Note. 2240 lbs. = 1 ton; 24 hours = 1 day.

8. How many cubic feet of steam will be used per hour by a pair of engines, 56 revolutions per minute, diameter of cylinder 48 inches, stroke 82 inches, and cut off at ⅞ of the stroke ?

Since the engines are double acting and there are two of them, therefore modify formulæ A and B, Article 13 by multiplying them by 2 × 2, and thus obtain the following

Formula

$$\textit{Volume} = \frac{\cdot 7854 \times (\text{diameter})^2 \times \text{stroke} \times \text{revolutions} \times 2 \times 60 \times \text{cut off} \times 2}{1728}$$

Hence, by substitution and cancelling in the above formula we have

Divide by 12
12
12
8

$$\text{Cubic feet} = \frac{\cdot 7854 \times \overset{4}{48} \times \overset{4}{48} \times 82 \times \overset{7}{56} \times 2 \times \overset{5}{60} \times 7 \times 2}{\underset{\substack{144\\12\\1}}{1728} \times \underset{1}{8}}$$

$$= \cdot7854 \times 4 \times 4 \times 32 \times 7 \times 2 \times 5 \times 7 \times 2$$

$$\begin{array}{rl}
\cdot7854 & \\
16 & = 4 \times 4 \\
\hline
47124 & \\
7854 & \\
\hline
12\cdot5664 & \\
32 & \\
\hline
251328 & \\
376992 & \\
\hline
402\cdot1248 & \\
\hline
\end{array}
\qquad
\begin{array}{rrl}
 & 402\cdot1248 & \\
 & 70 & = 7 \times 2 \times 5 \\
\hline
 & 28148\cdot7360 & \\
 & 14 & = 7 \times 2 \\
\hline
 & 112594944 & \\
 & 28148736 & \\
\hline
\text{Answer} & 394082\cdot304 & \text{cubic feet.} \\
\hline
\end{array}$$

9. The indicated H. P. of a pair of engines is 230, cylinder 35 inches diameter, stroke 24 inches, revolutions per minute 60; what is the pressure on the piston ?

There being a pair of engines, the H. P. of one is the half of the given H.P.; and the engine being double acting by Article 17, formula I we obtain the following

Formula.

$$\text{Pressure} = \frac{\text{H. P.}}{\cdot0000238 \times (\text{diameter}) \text{ in in.} \times \text{stroke, in ft.} \times \text{revolutions} \times 2}$$

Hence, by substitution, we have

$$\text{Pressure} = \frac{115}{\cdot0000238 \times 35 \times 35 \times 2 \times 60 \times 2}$$

Answer 16·44 lbs. per square inch.

Note. We obtain the same answer by using formula D Article 17.

10. The stays of a boiler are $1\frac{3}{8}''$ diameter and 16 inches apart, centre to centre; what should the safety valve be loaded at so that the strain on each square inch section of stay does not exceed 4500 lbs ?

Formula.

$$\text{Pressure} = \frac{\cdot7854 \times \text{diameter}^2 \times \text{strain}}{\text{apart}^2}$$

$$= \frac{\cdot7854 \times 11 \times 11 \times 4500}{16 \times 16 \times 8 \times 8}$$

Note. $1\frac{3}{8} = \frac{11}{8}$ Answer 26·102 lbs. per square inch.

11. An engineer is to have 5 per cent. on the value of the coal left at the end of the voyage; there were 49 tons left, value 17s. 6d. per ton; what was his per centage ?

Answer £2 2s. 10·5d.

Rule. $$\frac{\text{Price}\times\text{tons}\times\text{per cent.}}{100} = \frac{17\cdot5\times49\times5}{100}$$

12. If the total consumption of coal be 18 tons per day; how many baskets, each 48 lbs. will be required in a watch of 4 hours?

Answer 140 baskets.

Rule. $$= \frac{\text{lbs. in ton}\times\text{tons}}{\text{watches in day}\times\text{lbs. in basket}} = \frac{2240\times18}{6\times48}$$

13. A screw shaft is 19 feet 6 inches over all, 10 inches diameter, coupling flanges 15 inches diameter and 3½ inches thick; find the weight?

By formula A Article 10, dividing by the cubic inches in 1 lb., collecting and cancelling we obtain the following:

Formula. $$w = \frac{\cdot7854\ d^2 L + \cdot7854\ D^2 l}{3\cdot6} = \frac{\cdot7854\ (d^2 L + D^2 l)}{3\cdot6}$$

$$\therefore\ w = \frac{\cdot1309\ (d^2L + D^2\ l)}{\cdot6}$$

Where w = weight; in lbs.

$$\left.\begin{array}{ll} d = & \text{diameter of shaft}\\ D = & \text{,, \quad flange}\\ L = & \text{length of shaft — twice thickness flange}\\ l = & \text{length, or twice thickness, of flange}\end{array}\right\}\text{ in inches.}$$

Hence, by substitution, we have

$$\text{Weight} = \frac{\cdot1309\ (10^2\times227+15^2\times7)}{\cdot6}$$

$$\begin{array}{llllr}
 & 19'\ 6'' & 227 & & 15\\
3\tfrac{1}{2}\times2 = & \underline{7} & \underline{100} & = 10^2 & \underline{15}\\
 & 18\ 11 & 22700 & & 75\\
 & \underline{12} & \underline{+1575} & & \underline{15}\\
 & \underline{227} & 24275 & & 225\\
 & & \underline{\cdot1309} & & \underline{7}\\
 & & 218475 & & \underline{1575}\\
 & & 728250 & & \\
 & & \underline{24275} & & \\
 & & \cdot6)\underline{3177\cdot5975} & & \\
 & & \underline{5295\cdot996\text{ lbs.}} & &
\end{array}$$

Answer 2 tons 7 cwt. 1 qr. 3·996 lbs.

14. Fill up the tabular form given below from the following statement, and say whether you consider the quantity of coal remaining to be sufficient for the rest of the passage.

The S.S. "Planet" left port on the 7th of the month for a port of 2872 miles distant, with a stock of coals on board amounting to 162 tons. The distance run on the successive days were 201 miles, 212 miles, 190 miles, 194 miles, 196 miles, 198 miles, 184 miles, and 189 miles; the coals burnt on the successive days were 12¼ tons, 12½ tons, 13 tons, 11½ tons, 14 tons, 13 tons, 12 tons, and 12¼ tons.

DAILY REPORT OF STOCK OF FUEL.

Distance accomplished and coal consumed.				Remaining coal and distance to run.		
1 Dates	2 Miles run	3 Miles per ton	4 Tons coal consumed	5 Tons Coals left.	6 Miles to run.	7 Miles per ton.
7th	201	16·41	12¼	149·75	2171	14·5
8th	212	16·96	12½	137·25	1959	14·27
9th	190	14·62	13	124·25	1769	14·24
10th	194	16·87	11½	112·75	1575	13·97
11th	196	14·00	14	98·75	1379	13·96
12th	198	15·23	13	85·75	1181	13·77
13th	184	15·33	12	73·75	997	13·37
14th	189	15·43	12¼	61·50	808	13·14
	1564		100½			

TO FILL UP COLUMN 3.

201 ÷ 12·25 = 16·41; and so on.

TO FILL UP COLUMNS 5 AND 6.

Miles to run at first	2872	Tons at starting	162·00
Miles run the first day	201	Tons burnt first day	12·25
Miles to run at end of first day	2171	Tons left at end of first day	149·75
And so on.		And so on	

TO FILL UP COLUMN 7.

2171 ÷ 149·75 = 14·5 and so on.

TO FIND THE DISTANCE TO GO AND THE COAL LEFT IN THE BUNKERS.

	miles.		tons.
Whole distance	2872	Stock of coals at starting	162·0
Distance run	1564	Coal consumed	100·5
Distance to go...............	808	Coal left in bunkers	61·5

TO FIND WHETHER THE COAL BE SUFFICIENT.

Miles run		Miles to run		Tons used		Tons required
1564	:	808	: :	100·5	:	x

x = 51·92 tons required
61·50 tons in bunkers

9.58 tons over.

PAPER VIII.

1. Express in figures, Seven tons four hundredweights one quarter and nine pounds? Answer 7 tons 4 cwts. 1 qr. 9 lbs.

2. A ship has to make a voyage of 1600 miles with a stock of coals of 110 tons; after steaming 700 miles and consuming 42 tons, find how much coal she will have left at the end of the voyage, steaming at the same rate?

miles		miles		tons		tons	
As 700	:	1600	: :	42	:	96	burnt on voyage
						110	stock
				Answer		14	left.

3. A tank 3 feet 6 inches by 3 feet, and 2 feet 6 inches high, has 84 gallons of oil in it; how far is the oil from the top?

From Article 22. formula B we have the following *Formula*

$$\text{Height} = \frac{\text{gallons}}{\text{length} \times \text{breadth} \times 6{\cdot}25} = \frac{84}{3{\cdot}5 \times 3 \times 6{\cdot}25} = 1{\cdot}28$$

Then; height of tank 2·5′
,, oil — 1·28

oil from top 1·22 Answer.

4. An iron plate 5 feet 9 inches by 2 feet 3 inches, and ⅞″ thick; what is its weight?

Every square foot of iron plate ⅛ of an inch thick weighs 5 lbs.; hence from this fact and Article 6 formula A we obtain the following *Formula*

Weight = length × breadth × eighths in thickness × 5.

5·75 long	7 eighths in thickness
2·25 broad	5 lbs. every square foot ⅛ thick
2875	35 lbs. every square foot plate
1150	
1150	

12·9375 square feet
35 lbs. every square foot

646875
388125

52·8125 lbs. Answer 4 cwt. 0 qr. 4·81 lbs.

5. A voyage of 13 days with a supply of 12 gallons of oil; how many gills per day?

Rule.
$$\frac{\text{gallons} \times \text{gills in 1 gallon}}{\text{days}} = \frac{12 \times 32}{13}$$

Answer $29\frac{7}{13}$ gills.

6. The tally of baskets of coals for 24 hours was 80, 81, 85, 83, 77 and 84 each watch, each basket weighed 52 lbs.; what is the consumption in tons per day?

Rule.
$$\frac{\text{baskets} \times \text{lbs.}}{\text{lbs. in 1 ton}} = \frac{490 \times 52}{2240} = 11{\cdot}375$$

Answer 11·375 tons.

7. A safety valve 5" diameter was loaded with dead weights, 4 of 38 lbs. each and 8 of 75 lbs. each, the valve itself weighed 14 lbs., and the spindle 18 lbs.; what is the pressure of steam per square inch on the valve?

Formula
$$\text{Pressure} = \frac{\text{weight}}{{\cdot}7854 \times (\text{diameter})^2} = \frac{784}{{\cdot}7854 \times 25}$$

Answer 39·93 lbs. per square inch,

8. A stay 15" apart, centre to centre, and is eaten away to 1¼ diameter, the pressure is 24 lbs. per square inch; what is the strain per square inch section of the stay?

From Article 23 formula E, we have the following *Formula.*

$$\text{Strain} = \frac{(\text{apart})^2 \times \text{pressure}}{{\cdot}7854 \times \text{diameter}^2} = \frac{15 \times 15 \times 24}{{\cdot}7854 \times \frac{5}{4} \times \frac{5}{4}}$$

$$1\tfrac{1}{4} = \frac{1 \times 4 + 1}{4} = \frac{5}{4}, \qquad \text{Divide by } 5$$

$$= \frac{\overset{3}{15} \times \overset{3}{15} \times \overset{4}{24} \times 4 \times 4}{\underset{{\cdot}1309}{{\cdot}7854} \times \underset{1}{5} \times \underset{1}{5}} = \frac{3 \times 3 \times 4 \times 4 \times 4}{{\cdot}1309} \qquad \begin{matrix} 5 \\ 6 \end{matrix}$$

Answer 4400·3 lbs.

PAPER VIII.

1. Express in figures, Seven tons four hundredweights one quarter and nine-pounds? Answer 7 tons 4 cwts. 1 qr. 9 lbs.

2. A ship has to make a voyage of 1600 miles with a stock of coals of 110 tons; after steaming 700 miles and consuming 42 tons, find how much coal she will have left at the end of the voyage, steaming at the same rate?

miles		miles		tons		tons	
As 700	:	1600	: :	42	:	96	burnt on voyage
						110	stock
				Answer		14	left.

3. A tank 3 feet 6 inches by 3 feet, and 2 feet 6 inches high, has 84 gallons of oil in it; how far is the oil from the top?

From Article 22. formula B we have the following *Formula*

$$\text{Height} = \frac{\text{gallons}}{\text{length} \times \text{breadth} \times 6{\cdot}25} = \frac{84}{3{\cdot}5 \times 3 \times 6{\cdot}25} = 1{\cdot}28$$

Then; height of tank 2·5′
,, oil — 1·28

oil from top 1·22 Answer.

4. An iron plate 5 feet 9 inches by 2 feet 3 inches, and $\frac{7}{8}''$ thick; what is its weight?

Every square foot of iron plate $\frac{1}{8}$ of an inch thick weighs 5 lbs.; hence from this fact and Article 6 formula A we obtain the following *Formula*

Weight = length × breadth × eighths in thickness × 5.

7 eighths in thickness
5 lbs. every square foot $\frac{1}{8}$ thick
35 lbs. every square foot plate

5·75 long
2·25 broad
2875
1150
1150
12·9375 square feet
35 lbs. every square foot
646875
388125
452·8125 lbs.

Answer 4 cwt. 0 qr. 4·81 lbs.

5. A voyage of 13 days with a supply of 12 gallons of oil; how many gills per day?

Rule.
$$\frac{\text{gallons} \times \text{gills in 1 gallon}}{\text{days}} = \frac{12 \times 32}{13}$$

Answer $29\frac{7}{13}$ gills.

6. The tally of baskets of coals for 24 hours was 80, 81, 85, 83, 77 and 84 each watch, each basket weighed 52 lbs.; what is the consumption in tons per day?

Rule.
$$\frac{\text{baskets} \times \text{lbs.}}{\text{lbs. in 1 ton}} = \frac{490 \times 52}{2240} = 11{\cdot}375$$

Answer 11·375 tons.

7. A safety valve 5″ diameter was loaded with dead weights, 4 of 38 lbs. each and 8 of 75 lbs. each, the valve itself weighed 14 lbs., and the spindle 18 lbs.; what is the pressure of steam per square inch on the valve?

Formula

$$\text{Pressure} = \frac{\text{weight}}{\cdot7854 \times (\text{diameter})^2} = \frac{784}{\cdot7854 \times 25}$$

Answer 39·93 lbs. per square inch.

8. A stay 15″ apart, centre to centre, and is eaten away to 1¼ diameter, the pressure is 24 lbs. per square inch; what is the strain per square inch section of the stay?

From Article 23 formula E, we have the following *Formula.*

$$\text{Strain} = \frac{(\text{apart})^2 \times \text{pressure}}{\cdot7854 \times \text{diameter}^2} = \frac{15 \times 15 \times 24}{\cdot7854 \times \frac{5}{4} \times \frac{5}{4}}$$

$$1\tfrac{1}{4} = \frac{1 \times 4 + 1}{4} = \frac{5}{4}\,.$$

Divide by $\frac{5}{5}$ $\frac{}{6}$

$$= \frac{\overset{3}{15} \times \overset{3}{15} \times \overset{4}{24} \times 4 \times 4}{\underset{\cdot1309}{\cdot7854} \times \underset{1}{5} \times \underset{1}{5}} = \frac{3 \times 3 \times 4 \times 4 \times 4}{\cdot1309}$$

Answer 4400·3 lbs.

Weight as in question 4.

$$v = \cdot 7854\,(D^2 - d^2)\,h$$

$$\text{Weight} = \frac{\cdot 7854\,(D^2 - d^2)\,h \times 524}{1728} = \frac{\cdot 7854\,(25\cdot 25^2 - 24^2) \times 18 \times 524}{1728}$$

Answer 263·9169 lbs.

6. What is the weight of a pair of brasses 22″ long overall, diameter of journal 11½″, diameter of seat 14″ diameter of flanges 17″, thickness of each flange 1½″ and weight of 1 cubic inch of brass ·3 of a lb.? See figure 4.

Total length of brass	**22″**
Twice thickness of flange	**3**
Length of seat	**19**

$$\left\{(d^2\,\acute{L} + D^2\,l) - \cdot 7854\,\acute{d}^2\,L\right\} \times \cdot 3 \times 2$$

$$\left\{(14^2 \times 19 + 17^2 \times 3) - \cdot 7854 \times 11\cdot 5^2 \times 22\right\} \times \cdot 3 \times 2$$

Answer 1383·52722 lbs.

7. What is the weight of gun metal in a screw shaft liner, whose length is 46 inches, outer diameter 12½ inches, and thickness ¾ of an inch; if a cubic inch weigh ·3 of a lb.?

$$v = \cdot 7854\,(D^2 - d^2)\,h;\ \text{in cubic inches} \ldots\ldots\ldots\ldots \text{A}$$

$$\therefore \text{Weight} = \cdot 7854\,(D^2 - d^2)\,h \times \cdot 3;\ \text{in lbs.} \ldots\ldots\ldots\ldots \text{B}$$

$$\therefore \text{Weight} = \cdot 7854\,(12\cdot 5^2 - 11^2) \times 46 \times \cdot 3 \ldots\ldots\ldots\ldots \text{C}$$

Answer 382·05783 lbs.

8. The weight of a screw shaft liner is 382·05783 lbs., weight of a cubic inch is ·3 of a lb., length of liner 46 inches, outer diameter of liner 12½ inches; required the thickness of liner?

From formula B in question 7 we have

$$D^2 - d^2 = \frac{\text{weight}}{\cdot 7854\,h \times \cdot 3} \quad \therefore \quad D^2 - \frac{\text{weight}}{\cdot 7854\,h \times \cdot 3} = d^2$$

And thickness of liner $= \frac{1}{2}\,(D - d)$

$$\frac{\text{Weight}}{\cdot 7854\,h \times \cdot 3} = \frac{382\cdot 0573}{\cdot 7854 \times 46 \times \cdot 3}$$

·7854
46

47124
31416

36·1284
·3

10.83852

10·83852)382·05788(35·25
3251556

5690228
5419200

2709680
2167704

5419260
5419260

D = 12·5
12·5

625
250
125

D^2 = 156·25
—35·25

d^2 = 121·00

121(11 = d
121

D = 12·5
d = 11·0

2) 1·5

·75 = ¾ thickness
Answer.

9. Find the weight of a thrust block, there are 9 collars each 1½″ thick, with 1¼″ space between them, diameter of shaft 10″, of collars 12″, of seat 14″ and of flanges 16″, and the flanges are 1½″ thick. 1 cubic inch weighs ·3 of a lb.

Collars 1½ × 9 = 13½″ total length
Spaces 1¼ × 10 = 12½ ,,
Seat 26 ,,
Flanges 1½ × 2 = 3 ,,

$$\text{Weight}=\cdot7854\left\{\overset{\text{seat}}{(14^2-10^2)\times26}+\overset{\text{flanges}}{(16^2-10^2)\times3}-\overset{\text{collars}}{(12^2-10^2)\times13\cdot5}\right\}\times\cdot3$$

Answer 558·4194 lbs.

10. Make a sketch of a crank for a paddle shaft, and find its weight.

Pin boss; pin 6½″ diameter, boss 12″ diameter, and 8″ across. Shaft boss; shaft 9½″ diameter, boss 16″ diameter, and 10″ across. Bar 10″ wide at pin boss, and 12½″ at shaft boss, and 5″ across. Add ⅛ of the diameter of each boss to the length of the bar for the fillets, the length from centre to centre being 28″; 1 cubic inch weighs 8·6 lbs. See figure 5.

Formulæ

For bosses $v = \cdot7854\left\{(D^2-d^2)\,l+(\acute{D}^2-\acute{d}^2)L\right\}$; in cubic inches.
For bar $v = l\,b\,t$; in cubic inches.

BOSSES.

$$\text{Cubic inches} = \cdot 7854 \left\{ (12^2 - 6\cdot 5^2) \times 8 + (16^2 - 9\cdot 5^2) \times 10 \right\}$$

$$= 1941\cdot 1161$$

BAR.

$$28 + \left(-\frac{12}{2} - \frac{16}{2} + \frac{12}{6} + \frac{16}{6}\right) = 28 + \left(\frac{-36-48+12+16}{6}\right)$$

$$\text{Length of bar} = 18\cdot 6667 ; \quad \frac{10+12\cdot 5}{2} = 11\cdot 25 = \text{mean breadth.}$$

$$\text{Cubic inches bar} = 18\cdot 6667 \times 11\cdot 25 \times 5 = 1050\cdot 00178.$$

$$\text{Weight of crank} = \frac{1941\cdot 1161 + 1050\cdot 00178}{3\cdot 6} = 830\cdot 8661 \text{ lbs.}$$

11. A screw shaft is 21 feet over all, and 10″ diameter, coupling flanges 15 inches diameter, and 3 inches thick; find its weight?

3·6 cubic inches weigh 1 lb.

$$v = \cdot 7854\,(d^2\,L + D^2\,l) ; \text{ in cubic inches.}$$

$$\therefore \text{ Weight} = \frac{\cdot 7854\,(10^2 \times 246 + 15^2 \times 6)}{3\cdot 6}$$

Answer 5661·425 lbs.

12. How many tons of salt water, and how many of fresh, must be pumped into a boiler whose area of water level is 19 feet by 10 feet, to raise 8 inches in the glass?

$$\text{Tons of salt water} = \frac{l\,b\,h}{35} = \frac{19 \times 10 \times 8}{35 \times 12} = 3\cdot 61905 \text{ Answer.}$$

$$\text{Tons of fresh} = \frac{l\,b\,h \times 62\cdot 5}{2240} = \frac{19 \times 10 \times 8 \times 62\cdot 5}{2240 \times 12} = 3\cdot 53423$$

13. An Engineer has to have 3½ per cent. on the value of the coal left at the end of the voyage; there were 58 tons left at 24s. 6d. per ton; how much will he get?

$$\textit{Rule.} = \frac{\text{price} \times \text{tons} \times \text{per cent.}}{100} = \text{sum he will get.}$$

$$\frac{24\cdot 5 \times 58 \times 3\cdot 5}{100} = \pounds 2\ 9\text{s. } 8\cdot 82\text{d. Answer.}$$

PAPER I.

FIRST CLASS ENGINEERS.

1. If 15 lbs. of water at 42° be mixed with 110 lbs. of water at 210°; what will the temperature be ?

lbs.	lbs.	lbs.
15 } Add 110 }	15 42°	110 210°
125	30 60	1100 220
	630	23100

$$\frac{23100+630}{125} = 189{\cdot}8 \text{ Answer.}$$

2. $\dfrac{(18+7)^{\frac{1}{2}}}{(15-12)^2} = \dfrac{\sqrt{25}}{3^2} = \dfrac{5}{9}$ Answer.

Note. $5\times 5 = 25 \therefore 5 = \sqrt{25}$. Also $3\times 3 = 9 \therefore 9 = 3^2$

3. What is the radius of a circle whose area is 914 ?

Formula.

$$\text{Radius} = \frac{1}{2}\text{ diameter} = \frac{1}{2}\sqrt{\left(\frac{\text{area}}{\cdot 7854}\right)}$$

$$\text{Therefore} = \frac{1}{2}\sqrt{\left(\frac{914}{\cdot 7854}\right)} = \frac{1}{2}\sqrt{(1163{\cdot}7382)}$$

1163·7382(34·11 = *d*
9

64) 263
256

681) 773
681

6821) 9282
6821

$$\frac{34{\cdot}11}{2} = 17{\cdot}05 \text{ Answer.}$$

4. Sketch the half of a thrust block, and give the weight; there are 10 collars 1½" thick and spaces between them 1¼"; diameter of shaft 10", of collars 12", of seat 14", and of the flanges 16", the flanges are 1½" thick, and 1 cubic inch weighs ·3 of a lb ?

The shaft is a solid cylinder, and the collars, seat, and flanges, are hollow cylinders, and the volume of the collars is taken from the volume of the seat.

By Article 11 formula A we have the following *Formula*.

$$\text{Volume} = \cdot7854\left\{(\text{outside diameter})^2 - (\text{inside diameter})^2\right\} \times \text{length}$$

$1\tfrac{1}{2}'' \times 10 = 15''$ collars $1\tfrac{1}{2} \times 2 = 3''$ Flanges.
$1\tfrac{1}{4}'' \times 11 = 13\tfrac{3}{4}$ spaces
$28\tfrac{3}{4}$ seat.

Hence, by substitution in the formula we have

$$\text{Volume} = \cdot7854\left\{(\overset{\text{seat}}{14^2} - \overset{\text{shaft}}{10^2}) \times 28\cdot75 + (\overset{\text{flange}}{16^2} - \overset{\text{shaft}}{10^2}) \times 3 - (\overset{\text{collar}}{12^2} - \overset{\text{shaft}}{10^2}) \times 15\right\}$$

10 shaft	14 seat	28·75	16 flange	12 collar
10	14	96	16	12
100	56	17250	96	144
—	14	25875	16	—100
	196	2760·00	256	44
	—100	+468	—100	15
	96	3228	156	220
	—	— 660	3	44
		2568	468	660

	2568
	·7854
	10272
	12840
	20544
	17976
Cubic inches	2016·9072
Weight of 1 lb.	·3
Answer	605·07216 lbs.

5. An iron girder A B 17 feet long weighs 14 cwts, with a weight W of 8 tons at 7 feet from A, and another weight W′ of 4 tons at 8 feet from B; find the pressure borne at the supports A and B. Figure 3.

Since the weight of the girder is in cwts., reduce the weights W, W′ to cwts. Also find the distance from the weight W to B; thus

$$\begin{array}{lrl} W & 8 & \text{tons} \\ & 20 & \text{cwts} \\ \hline W & 160 & \text{cwts} \\ \hline \end{array} \qquad \begin{array}{lrl} W' & 4 & \text{tons} \\ & 20 & \text{cwts} \\ \hline W' & 80 & \text{cwts} \\ \hline \end{array} \qquad \begin{array}{lr} AB & 17 \\ AW & 7 \\ \hline WB & 10 \\ \hline \end{array}$$

Suppose the beam be suspended by a force F acting upwards at A, and the support at A be removed, and at first we shall not consider the weight of the beam; then we have

Force F × distance A B = weight W × distance WB + weight W' × distance $W'B$, or

$$F \times 17 = 160 \times 10 + 80 \times 8$$
$$= 1600 + 640$$

$$\begin{array}{r} 1600 \\ 640 \\ \hline 17)2240(\\ 17 \\ \hline 54 \\ 51 \\ \hline 30 \\ 17 \\ \hline 13 \end{array} \qquad \begin{array}{rcl} \text{cwts.} & & \\ 131\frac{13}{17} & = & F \\ 7 & = & \frac{1}{2}\text{ weight beam} \\ \hline 138\frac{13}{17} & = & \text{weight on } A \\ \hline \end{array} \qquad \begin{array}{rl} \text{cwts.} & \text{weights} \\ 160 & W \\ 80 & W' \\ 14 & \text{Beam} \\ \hline 254 & \text{Total} \\ 138\frac{13}{17} & \text{on } A \\ \hline 115\frac{4}{17} & \text{on } B \\ \hline \end{array} \Bigg\} \text{Ans.}$$

6. What pressure is allowed on a plate in the combustion chamber when the thickness of plate is $\frac{3}{8}''$, and the stays are 12″ apart?

Formula. $$B = \frac{60\,(T+1)^2}{S-6} = \frac{60\,(T+1)^2}{D^2-6}$$

Where B = boiler pressure; in lbs.
T = thickness of plate; in 16ths.
S = surface held up by 1 stay = D^2.
D = distance stays are apart; in inches.

Divide by 6

$$\therefore \text{Pressure} = \frac{60\,(6+1)^2}{144-6} = \frac{\overset{10}{60} \times 49}{\underset{23}{138}} = \frac{10 \times 49}{23}$$

$$\frac{3 \times 2}{8 \times 2} = \frac{6}{16}; \qquad \begin{array}{rl} 12 & = D \\ 12 & \\ \hline 144 & = D^2 \\ \hline \end{array}$$

Answer 21·3 lbs.

7. What would be the smallest diameter of stay in this case?

Formula. $d^2 = \dfrac{p\,D^2}{\cdot7854\,s} \quad \therefore \quad d = \sqrt{(\dfrac{p\,D^2}{\cdot7854\,s})}$

$$\begin{array}{rcrcl}
 & & \text{Where } d & = & \left.\begin{array}{l}\text{diameter of stay}\\ \text{distance stays are apart}\end{array}\right\}\text{in inches.}\\
 & & D & = & \\
 & & p & = & \left.\begin{array}{l}\text{pressure per square inch on plate}\\ \text{strain per square inch section of stay}\end{array}\right\}\text{in lbs.}\\
5000 & = & s & = &
\end{array}$$

$$\text{Square of Diameter} = \frac{21\cdot3 \times 144}{\cdot7854 \times 5000} = \cdot781054.$$

$$\text{Diameter} = \cdot883.$$

Answer $\dfrac{7\cdot064}{8}$ of an inch.

8. A steamer's bunker is filled with 55 tons of Welsh coal, and which are sufficient for a voyage of 1020 miles, and Lancashire coal is to Welsh, for space, in the ratio of 44 to 41, and for quality, in that of 8·8 to 10; what distance would the ship go if the bunker were filled with Lancashire coals?

$$\begin{array}{lllll}
44 & : & 41 & :: & 1020 \text{ miles}\\
\underline{10} & & \underline{8\cdot8} & & \underline{}\\
\underline{440} & & 328 & & \underline{102}\\
\underline{44} & & \underline{328} & & \\
11 & & \underline{360\cdot8} & & \\
 & & 90\cdot2 & & \\
 & & \underline{102} & & \\
 & & 1804 & & \\
 & & \underline{9020} & & \\
 & & 11)\underline{9200\cdot4} & & \\
\text{Answer} & & \underline{836\cdot4} \text{ miles.} & &
\end{array}$$

Note. In this solution, the first and third terms are cancelled by dividing each of them by 10; then the new first term and the second term are cancelled by dividing each of them by 4.

9. The temperature of the water in the hot well is 105°, and the vacuum in the condenser is 11·75 lbs.; but from some cause the temperature rises to 137°; what will the vacuum be?

Rule. $$\frac{(T-t)\,(T-50^\circ)\,t-50^\circ)}{100{,}000} = \text{decrease of vacuum.}$$

Where T = greater temperature
t = lesser ,,

Therefore $$\frac{(137^\circ-105^\circ)\,(137^\circ-50^\circ)\,(105^\circ-50^\circ)}{100.000} = 1{\cdot}531 \text{ lbs.}$$

	lbs.
Old vacuum	11·75
Decrease	1·531
New vacuum	10·219 Ans.

10. An engine is going 54 revolutions per minute, and the mean effective pressure of the steam is 20 lbs., but from some cause the vacuum is lowered 2 lbs. while the steam is the same; how many revolutions will the engine now make?

	lbs.	lbs.		lbs.		rev.		rev.
Pressure	20	20	:	18	: :	54^2	:	x^2
Loss of pressure	2							
Effective pressure	18							

$$\text{Therefore } x^2 = \frac{18 \times 54^2}{20} = 2624{\cdot}4$$

$$\text{Therefore } x = \sqrt{(2624{\cdot}4)} = 51{\cdot}2$$

Answer 51·2 revolutions.

11. There is £150 for salvage to be divided among three engineers; the chief engineer gets $\frac{9}{16}$, and the second $\frac{3}{10}$; what fractional part would the third get, and what would be each man's share?

$$\frac{9 \times 5}{16 \times 5} = \frac{45}{80};\ \frac{3 \times 8}{10 \times 8} = \frac{24}{80} \therefore \frac{9}{16} + \frac{3}{10} = \frac{45}{80} + \frac{24}{80} = \frac{69}{80}.$$

$$\frac{80-69}{80} = \frac{11}{80} = \text{third's share.}$$

9. If P = gross pressure at the beginning of the stroke
R = times the steam is expanded.

$$\text{Then, } P\times\left(\frac{18-R}{40}+\frac{\cdot85}{R}\right)-\text{back pressure} = \text{the mean effective pressure}$$

Question, What is the H.P., if the diameter of the cylinder be 66", stroke 36", steam gauge shewed 45 lbs., steam cut off at 10", revolution 32 per minute, and back pressure 3·8 lbs. ?

$$P = 45+15 = 60.$$
$$R = 36\div10 = 3{\cdot}6.$$

$$\therefore\ 60\times\left(\frac{18-3{\cdot}6}{40}+\frac{\cdot85}{3{\cdot}6}\right)-3{\cdot}8 = 31{\cdot}96.$$

$$\therefore\ H.P. = \frac{\cdot7854\times66^2\times31{\cdot}96\times3\times32\times2}{33000}$$

$$= 636{\cdot}169 \text{ Answer.}$$

10. A rectangular bar is 14 square inches in section and 42 inches long, there is a weight of 3500 lbs. at its end; the strain is 12000 lbs; what is the depth of the bar ?

$$\textit{Rule.} = \frac{\text{Strain}\times B\times D\times D}{6} = W\,l$$

Where B = breadth }
D = depth } in inches.
l = length }
W = Weight; in lbs.

Since the breadth × depth = 14, for $B\times D$ put 14, and proceed as follows. See Article 6 page 18.

$$\frac{\text{Strain}\times14\times D}{6} = W\times l$$

$$\therefore\ D = \frac{6\times W\times l}{\text{Strain}\times14} = \frac{6\times3500\times42}{12000\times14} = 5{\cdot}25 \text{ inches.}$$

11. In the last question, if the breadth be 2½ inches, depth 4½ inches, length 42 inches, and weight 3800 lbs.; what will be the strain per square inch section of stay ?

From the first formula in the previous question we obtain as follows. See Article 6 page 18.

$$\text{Strain} = \frac{6\times W\times l}{B\times D\times D} = \frac{6\times3800\times42}{2{\cdot}5\times4{\cdot}5\times4{\cdot}5} = 18915{\cdot}55 \text{ lbs. Answer}$$

EXAMINATION PAPERS AS GIVEN BEFORE 1876.

FIRST CLASS ENGINEERS.

PAPER V.

1. Find the side of a square whose area is 14884. Answer 122.

2. Some repairs to the engines occupied 2 men 7 weeks and 1 day, and have cost £25 16s. for wages; some larger repairs are necessary, which it is expected will occupy 10 men for 12 weeks 3 days; how much will be required to pay them at the same rate of wages?

Note. In this question 6 days are reckoned to 1 week.

$$\begin{array}{llllll} 2 \text{ men} & : & 10 \text{ men} & :: & £25\ 16s. & : £225 \text{ Answer.} \\ 43 \text{ days} & & 75 \text{ days} & & & \\ \hline 86 & & 750 & & & \end{array}$$

3. Required the weight to be placed on the end of a safety valve lever to be equal to 18 lbs. per square inch on the valve, the diameter of valve being 6 inches, the distance from the fulcrum to the valve 3 inches, and from the valve to the weight 13 inches?

The effective weight of the lever is 62 lbs., and the weight of the valve 11 lbs.

$$\textit{Formula. } W = \frac{\left\{(\cdot 7854\, d^2\, p) - (W' + w)\right\} l}{L + l}$$

$$\therefore \text{Weight on end} = \frac{\left\{(\cdot 7854 \times 36 \times 18) - (62 + 11)\right\} \times 3}{13 + 3}$$

$$\text{Answer} = 81{\cdot}7386 \text{ lbs.}$$

$$\begin{array}{rcl} \text{Where } W & = & \left.\begin{array}{l} \text{weight at end of lever} \\ \text{weight of lever} \\ \text{,, valve} \\ \text{pressure per square inch} \end{array}\right\} \text{in lbs.} \\ W' & = & \\ w & = & \\ p & = & \\ d & = & \left.\begin{array}{l} \text{diameter of valve} \\ \text{distance from valve to weight} \\ \text{,, ,, fulcrum} \end{array}\right\} \text{in inches.} \\ L & = & \\ l & = & \end{array}$$

4. Required the weight to be placed on a double beat valve to be equal to 18 lbs. per square inch, the diameter of the valves being 6½ and 5½ inches?

Formula. Weight $= \cdot7854\,(D^2-d^2)\times$ pressure

Where $D =$ diameter of larger valve
$d =$ „ smaller „

Hence; weight $= \cdot7854(6\cdot5^2-5\cdot5^2)\times18 = 169\cdot6464$ lbs. Ans.

5. What is the total pressure on the flat bottom of a boiler 18 feet 11 inches by 6 feet 10 inches, the pressure of steam in the boiler being 16 lbs. per square inch, and the height of water in the boiler 6 feet 8 inches; also the number of stays 1½ inches in diameter required, so that every square inch section of the stays shall bear 4500 lbs.?

$$\textit{Formula.}\quad n = \frac{P}{\cdot7854\,d^2\,s} = \frac{l\,b\left(\dfrac{h}{2\cdot305}+p\right)}{\cdot7854\,d^2\,s}$$

$$\begin{array}{rcl} \text{Where } n & = & \text{number of stays} \\ P & = & \left.\begin{array}{l}\text{total pressure} \\ \text{pressure of steam} \\ \text{strain on every square inch of stay}\end{array}\right\}\text{in lbs.} \\ p & = & \\ s & = & \\ h & = & \text{height of water; in feet.} \\ l & = & \left.\begin{array}{l}\text{length of boiler} \\ \text{breadth ,,} \\ \text{diameter of stays}\end{array}\right\}\text{in inches.} \\ b & = & \\ d & = & \end{array}$$

$$\text{Hence; stays} = \frac{227\times82\times18\cdot71}{\cdot7854\times1\cdot5\times1\cdot5\times4500}$$

$$\text{Answers}\begin{cases}\text{Total pressure } 348267\cdot94 \text{ lbs.} \\ \text{Stays} \qquad\qquad 43\cdot8\end{cases}$$

6. Required the heating surface in the tubes and tube plates of a boiler, the tubes being 3 inches in diameter, 8 feet 9 inches in length, and 262 in number, and the plates 12 feet 10 inches long by 9 feet 4 inches wide?

$$\textit{Formula.}\quad h = \frac{3\cdot1416\,d\,l\,n+(L\,w-\cdot7854\,d^2\,n)\times2}{144}$$

$$\begin{array}{rcl} \text{Where } h & = & \text{whole heating surface; in square feet.} \\ d & = & \left.\begin{array}{l}\text{diameter of tubes} \\ \text{length ,,} \\ \text{length of plates} \\ \text{width ,,}\end{array}\right\}\text{in inches.} \\ l & = & \\ L & = & \\ w & = & \\ n & = & \text{number of tubes.} \end{array}$$

Hence; heating surface

$$= \frac{3{\cdot}1416 \times 3 \times 105 \times 262 + (154 \times 112 - {\cdot}7854 \times 9 \times 262) \times 2}{144}$$

Answer = 2014·22 square feet.

7. The pitch of a propeller is 16 feet, making 56 revolutions per minute; what will be the progression of the propeller; and the rate of the ship allowing 15 per cent. slip?

$$\text{Rule 1.} = \frac{\text{pitch} \times \text{revolutions} \times 60}{6080} = \text{progression.}$$

$$\text{Rule 2.} = \text{progression} - \text{per centage} = \text{rate of ship.}$$

$$\text{Hence.}\ \frac{16 \times 56 \times 60}{6080} = 8{\cdot}84 \text{ knots; progression.}$$

$$\text{And}\ 8{\cdot}84 - \frac{8{\cdot}84 \times 15}{100} = 7{\cdot}51 \text{ knots; rate of ship.}$$

8. Sea water contains $\frac{1}{33}$ of solid matter, and the water in the boiler is not to contain more than $\frac{3}{33}$; what proportion must the quantity blown off bear to the quantity evaporated?

As 1 to 2.

PAPER VI.

FIRST CLASS.

1. The effective pressure per square inch on the surface of a piston is 56 lbs., the total pressure is 14½ tons; what is the diameter of the piston?

Formula.

$$\text{diameter} = \sqrt{\left(\frac{\text{tons}\times 2240}{\cdot 7854\times\text{pressure}}\right)} = \sqrt{\left(\frac{14{\cdot}5\times 2240}{\cdot 7854\times 56}\right)}$$

Therefore, diameter = 27·17 inches. Answer.

2. If the drag of friction be ·042 of the pressure, what H.P. is expended in the friction of a thrust bearing with 8 collars, the mean diameter of the collars being 12½ inches, the shaft making 60 revolutions per minute, and the average pressure being 6½ tons?

Rule. $$\text{H.P.} = \frac{2240\times\text{tons}\times\text{friction}\times 3{\cdot}1416\times\text{diameter}\times\text{revolutions}}{12\times 33000}$$

Answer 3·63 horse power.

3. If the drag of friction be ·032 of the pressure, and if the pressure of the connecting rod on the crank pin be uniform; what per centage of that is lost by friction on the crank pin, the stroke being 36 inches, and the diameter of the crank pin 10 inches?

Rule. $$\text{Per centage} = \frac{3{\cdot}1416\times\text{diameter}\times\text{friction}\times 100}{12\times 2\times\text{stroke (in feet)}}$$

$$\text{Therefore, per centage} = \frac{3{\cdot}1416\times 10\times{\cdot}032\times 100}{12\times 2\times 3} = 1{\cdot}396 \text{ Ans.}$$

4. If the maximum strain to be allowed on iron be taken as 9000 lbs. per square inch; what should be the depth at the fulcrum of an iron lever whose thickness is 2½ inches, to support ½ ton at the extremity, the lever arm being 24 inches long?

Formula. $$\text{Square of depth} = \frac{6\times\text{weight}\times\text{length of lever}}{\text{strain}\times\text{thickness of lever}}$$

PAPER VI.

FIRST AND SECOND CLASS.

1. $(9-3)^2 + \sqrt{\left\{2\,(24-4^2)\right\}} = 6^2 + \sqrt{\left\{2\,(24-16)\right\}}$

$= 36 + \sqrt{(2\times 8)} = 36 + \sqrt{16} = 36+4 = 40$ Ans.

2. Molesworth in his 17th Edition, at page 258, says, the feed water should be about ·07 cubic feet, or nearly ½ gallon per N.H.P. per minute for condensing engines.

If 1 lb. of coal evaporate 8 lbs. of water, how many lbs. of coal will be required to evaporate the above allowance per N.H.P. per hour; also consumption of coal per N.H.P. is 10 lbs. per hour; what is the weight of feed water used as steam per minute?

62·5 lbs.; weight of 1 cubic foot of fresh water.
·07 cubic foot of feed water per N.H.P. per minute.

4·375 lbs. of water ,, ,,
60

8)262·500 lbs ,, ,, per hour.

32·8125 lbs. of coal per N.H.P. per hour.

10 lbs. of coal consumed per N.H.P. per hour.
8 lbs. of water evaporated by every lb. of coal.

6,0)8,0 lbs. of water evaporated per N.H.P. per hour.

$1\frac{2}{6} = 1\frac{1}{3}$ lbs. of water used as steam per minute.

3. In altering the pitch of a screw propeller it is found that when the mean effective pressure of the indicator diagram is not altered the product of the pitch, and the square of the knots per hour is not altered. Pitch was 16 feet this was changed to 18 feet, then it was found that the knots had changed from 10 to 9·4.

We have $16\times 10^2 = 1600$ and $18\times 9{\cdot}4^2 = 1590{\cdot}48$.

Fahrenheit. The difference between the temperature of 37 lbs. of steam and 55 lbs. of steam is 20°; in what time will the pressure rise from the former to the latter pressure if all the valves are shut and the fires in action?

Rule. Time in minutes $= \dfrac{\text{length} \times \text{breadth} \times \text{depth} \times \text{difference}}{525 \times 11{\cdot}5}$.

Therefore; time $= \dfrac{17{\cdot}5 \times 18 \times 10{\cdot}5 \times 20}{525 \times 11{\cdot}5} = 10{\cdot}9565$ minutes.

Answer 10m. 57·39s.

Note. Formula A, Article 28, has been used in the solution of this question, on the supposition that the water in the boiler was salt.

If the water be fresh, use formula B, namely:

$$\text{Time} = \frac{l\ b\ d\ t \times 2{\cdot}5}{8 \times 4 \times c \times 112}$$

$$= \frac{17{\cdot}5 \times 18 \times 10{\cdot}5 \times 20 \times 2{\cdot}5}{8 \times 4 \times 11{\cdot}5 \times 112}$$

= 10 min. 41·98 sec. Answer.

PAPER I.

FIRST AND SECOND CLASS.

1. $$\frac{(24+25)^{\frac{1}{2}}}{(14-11)^2} = \frac{49^{\frac{1}{2}}}{3^2} = \frac{7}{9} \quad \text{Answer.}$$

2. A bonus of £160 has to be divided among three engineers in the proportion of their wages, A's wages are £130, B's £100, and C's £60; what share of the £160 will each man get?

Wages

A's 130
B's 100
C's 60
Total 290

$$\begin{array}{lrrr} & & \text{£} & \text{s.} \\ \text{A's share of bonus} = \frac{130 \times 160}{290} & = & 71 & 14\frac{14}{29} \\ \text{B's do.} = \frac{100 \times 160}{290} & = & 55 & 3\frac{13}{29} \\ \text{C's do.} = \frac{60 \times 160}{290} & = & 33 & 2\frac{2}{29} \\ \hline \text{Total bonus} & = & 160 & 0 \end{array}$$

3. A steam pipe is 13″ diameter, and it goes inside the boiler, the part inside has slots 7″ long and ¼″ wide; how many slots must there be to make an area equal to double the sectional area of the pipe; and what are those slots for?

$$\text{Number of slots} = \frac{\text{twice sectional area of pipe}}{\text{area of slots}}$$

$$= \frac{\cdot 7854 \times 13 \times 13 \times 2}{7 \times \cdot 25} = \frac{\cdot 1122 \times 13 \times 13 \times 2}{\cdot 25} = 151{\cdot}694 \text{ Ans.}$$

The slots are to prevent priming.

4. Make a sketch, and find the weight of a T headed piston rod for an oscillating engine; the dimensions of the rod are: length over all 12′ 4″ diameter 8″, the T head is 31″ long, 10″ wide, and 5″ thick.

Length over all 12′ 4″
Thickness of T head 5
Length of rod 11 11
12
Length in inches 143

$$\frac{(\cdot 7854 \times 8^2 \times 143) + (31 \times 10 \times 5)}{3{\cdot}6} = 2427{\cdot}217\text{lbs}$$

Answer 1 ton 1 cwt 2 qrs. 19·217 lbs.

By Articles 9 and 10 the formulæ for the solution of this question is:

$$\left(\frac{\cdot 7854\ d^2L+l\ b\ h}{\text{cubic inches in 1 lb.}}\right) = \text{weight.}$$

See figure 14.

5. *Note.* The pressure on the guide has the same proportion to the pressure on the piston as the length of the crank has to the length of the connecting rod.

Question. The piston is 49″ diameter, pressure 30 lbs. per square inch, length of crank 24,″ and that of connecting rod 8′ 4″, the guide block is 12″ by 10″; what is the strain per square inch on the guide block? Make a sketch of it, shewing the position of greatest strain.

$$\begin{array}{lll} \text{Length of rod} & 8'\ 4'' & \\ & \underline{12} & \cdot 7854\times 49^2\times 30 = 56572\cdot 362 \text{ lbs. on piston.} \\ \text{Length in in.} & \underline{100} & \end{array}$$

As 100″ : 24″ : : 56572·362 : 13577·3669; on block.

Area of block 12″×10″ = 120.

13577·3669÷120 = 113·1447 lbs. per square inch Answer.

A formula for the solution of this question may be investigated as follows:—

$$\left.\begin{array}{lll} \text{Let } s & = & \text{strain per square inch section of guide} \\ x & = & \text{total pressure on the guide} \\ y & = & \quad ,, \qquad \text{piston} = \cdot 7854d^2p \end{array}\right\}\text{in lbs.}$$

$$\left.\begin{array}{lll} c & = & \text{length of crank pin} \\ r & = & \quad ,, \quad \text{connecting rod} \\ l & = & \quad ,, \quad \text{guide block} \\ b & = & \text{breadth} \quad ,, \end{array}\right\}\text{in inches.}$$

$$\text{Then } x : y :: c : r \ \therefore\ x = \frac{c\,y}{r} = \frac{\cdot 7854\ d^2\ p\ c}{r}$$

Hence we have the *Formula*

$$s = \frac{\cdot 7854\ d^2pc}{l\,b\,r} = \frac{\cdot 7854\times 49\times 49\times 30\times 24}{12\times 10\times 100} = 113\cdot 1447 \text{ lbs.}$$

See figure 13.

6. A safety valve is 6″ diameter, and has a spiral spring 5″ diameter, outside and $\frac{7}{8}$″ thickness of steel; what is the pressure per square inch?

Rule. $$\frac{8000\,S^3}{d} = \text{Total weight.}$$

Where S = thickness of steel
d = diameter of spring, from centre to centre.

Now, if the total weight, or pressure, be divided by the number of square inches in the area of the valve, the quotient will be equal to the pressure on every square inch of the valve; hence for the solution of the question we have the following *formula*:

$$\text{Pressure} = \frac{8000\,S^3}{{\cdot}7854\,D^2\,d}; \text{ where } D = \text{ diameter of valve.}$$

Hence, by substitution and cancelling we have

$$\text{Pressure} = \frac{8000\times7\times7\times7}{{\cdot}7854\times6\times6\times8\times8\times8\times\frac{33}{8}} =$$

$$\frac{8000\times7\times7\times7\times8}{{\cdot}7854\times6\times6\times8\times8\times8\times33}$$

$$= \frac{125\times7\times7\times7}{{\cdot}7854\times6\times6\times33} = 45{\cdot}95 \text{ lbs. Answer.}$$

Note. 5″ diameter of spring
$\frac{7}{8}$ thickness of steel

$$d = \underline{\overline{4\tfrac{1}{8}}} = \frac{33}{8}$$

7. The boiler contains 58 tons of fresh water on starting on a voyage, the water in the hot well, through some leak, is $\frac{1}{9}$th the saltness of the sea; how many tons of water must have evaporated during the voyage, there having been no blow off, the boiler water at the end of the voyage being 2·3 times the saltness of the sea water?

$58\times9\times2{\cdot}3 = 1200{\cdot}6$ tons Answer.

8. A slide valve has 8½″ travel, 2⅛″ lap on the steam side, and $\frac{3}{16}$ lap on the exhaust side, and ⅛″ lead; to what extent is the exhaust port open when the piston is at the extreme end of the stroke?

Steam lap + lead — exhaust lap = exhaust open.

$$2\frac{1}{8}+\frac{1}{8}-\frac{3}{16} = 2\frac{2+2-3}{16} = 2\tfrac{1}{16} \text{ Answer.}$$

9. *Note.* The weight of steam that will escape into a space in which the pressure does not exceed 58 per cent. of the gross pressure of the steam is, in 70 seconds, just equal to the gross pressure of the steam upon an area equal to the area of the orifice?

There is a crack in the metal between the low pressure cylinder exhaust port and the steam jacket, the sectional area of which is equal 4·2 square inches, and the steam in the jacket is 65 lbs. by guage; if 1 lb. of coal produce 9 lbs. of steam, what is the loss in steam and coal in 24 hours.

Let a = area of section of crack.
g = gross pressure.

$$\text{Then } \overset{\text{sec.}}{70} : \overset{\text{sec.}}{60} :: \overset{\text{lbs.}}{a\,g} : \overset{\text{lbs.}}{\frac{60\,a\,g}{70}} = \overset{\text{lbs.}}{\frac{6}{7}}\,a\,g, \text{ in 1 minute.}$$

$$\text{Hence; tons in 24 hours} \doteq \frac{a\,g \times 6 \times 60 \times 24}{7 \times 2240} = \cdot 55102\,a\,g.$$

Hence we have the *formula*.

$$\text{Tons} = \cdot 55102\,a\,g$$

65 guage
15 atmosphere

$80 = g$ $\qquad \cdot 55102 \times 336 \doteq 185{\cdot}1427$ tons; loss of steam.
$4{\cdot}2 = a$ $\qquad 185{\cdot}1427 \div 9 = 20{\cdot}5714$ tons; loss of coal.

$336{\cdot}0 = a\,g$

10. If 1 lb. of steam condensed raise 1000 lbs. of water 1° Fahrenheit, and if the temperature of sea water be 58° and that of the discharge water be 92; what weight of water will be required to condense the steam escaping by the above crack?

The sea water goes into the condenser at 58° F., and comes out at 92° F., it is therefore raised 92°—58° = 34°.

Now, if 1 lb. of steam raise 1000 lbs. of water 1°, then it will require 34 lbs. of steam to raise 1000 lbs. of water 34°.

$$\text{And } \overset{\text{lbs. steam}}{34} : \overset{\text{lb. steam.}}{1} :: \overset{\text{lbs. water.}}{1000} : \overset{\text{lbs. water.}}{\frac{1000 \times 1}{34}}$$

The following is the general *Formula.*

$$\text{Tons water} = \frac{\text{tons steam} \times 1000}{T - t}$$

Where T = greater temperature of the water.
t = lesser ,, ,, ,,

$$\text{Therefore } \frac{185{\cdot}1427 \times 1000}{92-58} = 5445{\cdot}878 \text{ tons water Answer.}$$

11. A Second Class Engineer has, through his carelessness, ruined the combustion chamber top, and the law courts have ordered him to pay the cost of the repairs, amounting to £53 ; his wages are 56 shillings per week ; his owners agree to accept payment by instalments of $\frac{1}{7}$th of his weekly pay ; how many weeks will it take to pay it, and how much will be the last instalment ?

$$\begin{array}{ccccccccc} \text{s.} & \text{s.} & & \text{£} & & & \text{week.} & & \text{weeks.} \\ 7)\underline{56} & 8 & : & 53 & : & : & 1 & : & x \\ 8 & & & & & & & & \end{array}$$

$\left.\begin{array}{l} 132\frac{4}{8} \text{ weeks} \\ 4 \text{ shillings last instalment} \end{array}\right\}$ Answer.

12. The piston has 2842·48 square inches of area ; find the length of a shoe 15" broad, allowing 10 square inches of piston to 1 square inch of shoe ?

$2842{\cdot}48 \div 10$ = area of shoe.

$284{\cdot}248 \div 15$ = 18'·9499 length of shoe Answer.

PAPER II.

FIRST AND SECOND CLASS.

1. Subtract the first line from the third line, and divide the remainder by the sixth line.

·0007
·000017
·004724
·897
·24
·0725 Answer ·0555.

2. There are 2 pistons of 31″ and 59″ diameter, at 30 circular inches per N.H.P., and 1650 square feet of effective surface in the condenser: how many square feet of condenser surface is that per N.H.P.?

$$\text{N.H.P.} = \frac{31^2+59^2}{30} = 148{\cdot}066.$$

Square feet per N.H.P. = 1650÷148·066 = 11·14 Answer.

3. Find how many tubes there are to a fire grate 5′ 4′ by 3′ 3″, length of tubes 6′ 1″, and 3″ diameter; there are 15 lbs, of coal burnt per square foot of fire grate, and 1 lb. per square foot of tube surface?

$$\begin{array}{lll} 5'\,4''; & 3'\,3''; & 6'\,1''; \\ 12 & 12 & 12 \\ \hline 64 & 39 & 73 \\ \hline \end{array} \qquad \frac{64\times39\times15}{3{\cdot}1416\times3\times73} = 54{\cdot}42 \text{ tubes Answer.}$$

4. If 1 lb. of coal evaporate 7·8 lbs. of water, when the guage is at 56 lbs., how many cubic feet of steam will this be for 1 lb. of coal?

$$\frac{410+P\div4}{P+1} = \text{cubic feet of steam from 1 lb. of water.}$$

$$\therefore \left(\frac{410+P\div4}{P+1}\right)\times7{\cdot}8 = \text{cubic feet of steam from 7·8 lbs. of water.}$$

Where P = gross pressure.

$\therefore \left(\frac{410+17\cdot75}{72}\right)\times7\cdot3 \quad = \quad 46\cdot34$ cubic feet of steam Answer.

5. Instead of using 8½ gallons per day of oil at 3s. 4d. per gallon, you use 6½ gallons per day at 4s. 6d. per gallon; what difference of expense is there in 84 days ?

gall.	gall.	s.	d.		£	s.
8·5 ×	84 ×	3	4	=	119	0
6·5 ×	84 ×	4	6	=	133	17
Difference				=	3	17 Answer.

6. What proportion of area does the steam pipe of 9″ diameter bear to that of the cylinder of 45″ diameter ?

$$\frac{\text{Area of pipe}}{\text{Area of cylinder}} = \frac{a}{A} = \frac{\cdot7854\ d^2}{\cdot7854\ D^2} = \frac{d^2}{D^2} = \frac{9^2}{45^2}$$

$$\frac{9^2}{45^2} = \frac{9\times9}{45\times45} = \frac{1\times1}{5\times5} = \frac{1}{25}\ \text{Answer; or as } 1 : 25$$

Where a = area of pipe d = diameter of pipe.
A = ,, cylinder D = ,, cylinder.

7. Find the safe working pressure to be carried in a circular boiler whose diameter is 11 feet 6 inches, and thickness of plate $\frac{15}{16}$ of an inch, seams double rivetted ?

$$\textit{Formula.}\quad P = \frac{s\times2\,t''}{d''} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathrm{A}$$

Where P = bursting pressure per square inch, supposing there were no seam.
s = 23 tons × 2240 lbs. in 1 ton = 51520 strain; in lbs.
t'' = thickness of plate } in inches.
d'' = diameter of boiler }

For double rivetted seams; take 70 per cent. of the above.
,, single ,, 50 ,, ,,

Take from one-sixth to one-eighth of the bursting pressure for the safe working pressure, according to quality of material and workmanship.

Suppose one-sixth be taken, then formula A may be modified as follow, where P is the safe working pressure:

Divide by 10
10
8
8
2

$$P = \frac{s \times 2\,t'' \times 70}{6 \times d'' \times 100} = \frac{51520 \times 2 \times 15 \times 70}{6 \times 138 \times 16 \times 100}$$

$$\begin{array}{r} 11'\ 6'' \\ 12 \\ \hline 138 \\ \hline \end{array}$$

$$\text{by cancelling} = \frac{644 \times 5 \times 7}{6 \times 46} = 81{\cdot}67 \text{ lbs. per sq. in. Ans.}$$

The safe working pressure may be found as follows :

$\frac{15}{16}$ = thickness of plate = ·9375 in decimals. Shift the decimal point three places to the right hand, and divide by the diameter of the boiler ; in feet, as follows.

$$16\left\{\begin{array}{l} 4)15 \\ \hline 4)\ 3{\cdot}75 \\ \hline \quad {\cdot}9375 \\ \hline \end{array}\right.$$

$$\begin{array}{l} 11{\cdot}5)937{\cdot}5(81{\cdot}52 \text{ lbs.;} \\ \quad\ \ 920 \\ \hline \quad\ \ 175 \\ \quad\ \ 115 \\ \hline \quad\ \ \ 600 \\ \quad\ \ \ 575 \\ \hline \quad\ \ \ \ 250 \\ \quad\ \ \ \ 230 \\ \hline \end{array}$$

which only differs ·15 lb. from the former answer.

8. A coal bunker is 22′ wide at the top, 19′ 6″ wide at the middle, and 18′ 6″ wide at the bottom ; how many tons will it hold if it be 27′ long, and 17′ 6″ high ?

Wide at top	22·0
4 times wide at middle	78·0
Wide at bottom	18·5
	6)118·5
Mean width	19·75

Wide at middle	19·5
	4
4 times	78·0

$$\frac{\text{Mean width} \times \text{length} \times \text{height}}{45} = \frac{19{\cdot}75 \times 27 \times 17{\cdot}5}{45} = 207{\cdot}375$$

Answer 207·375 tons.

9. What lift will a steam valve have when the area of escape is $\frac{1}{8}$ the area of the valve, the diameter of the valve being $6\frac{1}{4}$ inches ?

Area of escape of steam = $3{\cdot}1416\, d\, h$ = surface cylinder.
Area of valve = ${\cdot}7854\, d^2$ = area of circle.

$$\therefore\ h = \frac{7854\ d^2}{3{\cdot}1416\ d \times 8} = \frac{d}{4 \times 8}$$

Hence, we have the *Rule.*

Height of lift = (diameter × fraction of area) ÷ 4

$$= \frac{6{\cdot}5 \times 1}{4 \times 8}$$

8)6·5

4) ·8125

Ans. ·203125 = $\frac{2}{10}$ = $\frac{1}{5}$ of an inch nearly.

10. A cylinder port is 22″ long × $2\frac{3}{4}$″ broad, the valve has $1\frac{1}{2}$″ lap, the travel of valve is 7″; find the greatest area the valve is open for steam ?

Rules.

Lap + port—travel ÷ 2 = port not open ....A
Port—port not open = port open for steam......................B

∴ By A. $1\frac{1}{2} + 2\frac{3}{4} - 3\frac{1}{2} = \frac{3}{4}$ = port not open.
And by B. $2\frac{3}{4} - \frac{3}{4} = 2$ = port open for steam.

Therefore, area = 22 × 2 = 44 square inches Answer.

PAPER III.

FIRST AND SECOND CLASS.

1. If the pressure by guage be 62 lbs., and the area of the water level in the boiler be 144 square feet, how long would it take to lower it 8″ through a $\frac{7}{8}$ rivet being blown out of the ash pit?

Rule. $2\frac{1}{2}\, d^2 \sqrt{P}$ = cubic feet of water blown out per minute.

Hence, we have the following *Formula.*

$$\text{Time; in minutes} = \frac{\text{cubic feet of water lowered}}{\text{cubic feet of water blown out per minute}}$$

$$= \frac{144 \times 8}{2\frac{1}{2}\, d^2 \sqrt{P} \times 12}$$

Where d = diameter of rivet

$2\frac{1}{2} = \frac{5}{2}$ $\quad P$ = pressure by guage

$\sqrt{62} = 7{\cdot}874.$

$$\therefore \quad \text{Time} = \frac{144 \times 8}{\frac{5}{2} \times \frac{7}{8} \times \frac{7}{8} \times 12 \times 7{\cdot}874}$$

$$= \frac{144 \times 8 \times 2 \times 8 \times 8}{5 \times 7 \times 7 \times 12 \times 7{\cdot}874} = \frac{12 \times 8 \times 8 \times 8}{5 \times 7 \times 7 \times 3{\cdot}937}$$

$$= 6{\cdot}3697 \text{ minutes} = 6\text{m. } 22{\cdot}182\text{sec. Answer.}$$

Note. This is not a second class question.

2. It takes 800 lbs. at a leverage of 12″ to break a stud 1″ diameter, what weight would be necessary to break a $\frac{3}{4}$″ stud at a leverage of 20″?

$$\frac{800 \times 12 \times 3 \times 3 \times 3}{20 \times 4 \times 4 \times 4} = \frac{10 \times 3 \times 3 \times 3 \times 3}{4} = 202{\cdot}5 \text{ lbs. Answer.}$$

3. What is the weight of a cast iron ball 9″ diameter, if a cubic inch weigh ·257 lb.?

Formula. Weight = cubic inches × weight of 1 cubic inch

$$= (\cdot 7854 \times 9^3 \times \tfrac{2}{3}) \times \cdot 257 = 98{\cdot}098 \text{ lbs. Ans.}$$

4. The inside diameter of a condenser tube is $\frac{7}{8}''$, there are $2\frac{1}{2}$ square feet of surface per I.H.P., the tubes are 6 feet long, there are 800 lbs. of cold water per I.H.P., and it circulates 3 times through the tubes; find the velocity of its passage?

Rule. $$V = \frac{L\,T\,P}{80\,D\,S}.$$

Where V = velocity in feet per minute
L = length
T = time the water circulates
P = lbs. of cold water per I.H.P.
D = diameter of tubes
S = surface.

$$\therefore\ V = \frac{6\times3\times800}{80\times\frac{7}{8}\times\frac{5}{2}} = \frac{6\times3\times800\times8\times2}{80\times7\times5}$$

By cancelling $$= \frac{6\times3\times2\times8\times2}{7} = \frac{576}{7} = 82\cdot2857 \text{ feet per minute Ans.}$$

5. Steam is carried for 22″ of the stroke, and there is $1\frac{1}{2}''$ clearance, the guage shows 60 lbs.; if the steam of one stroke were condensed, what would be the thickness of the layer of water, in 16ths on the top of the piston?

$$(\text{Stroke}+\text{clearance})\div\frac{P+1600}{P+1} = T$$

Where P = gross pressure
T = thickness of layer of water in 16ths

$$\therefore\ (22+1\cdot5)\div\frac{1675}{76} = \frac{23\cdot5\times76}{1675} = 1\cdot07 \text{ Answer in 16ths.}$$

lbs.
Guage 60
Atmo. 15
Gross 75

6. Diameter of the high pressure piston 37′, stroke 35″, steam carried for half the stroke, there are 1290 cubic feet of steam capacity in the boiler; how many strokes will be required to carry that amount off?

$$\text{Number of strokes} = \frac{\text{cubic feet of steam in boiler}}{\text{cubic feet of steam drawn every stroke}}$$

$$= \frac{1290}{\frac{\cdot 7854\ d^2\ \text{half-stroke}}{1728}} = \frac{1290 \times 1728}{\cdot 7854 \times 37 \times 37 \times 17{\cdot}5}$$

$$\text{By cancelling} = \frac{258 \times 288}{\cdot 1309 \times 37 \times 37 \times 3{\cdot}5} = 118{\cdot}5 \text{ Answer.}$$

7. If ·4536 Kilogramnes = 1 lb., and you pay £11 17s. 4d. for 250 kilos. of tallow, how much will you pay per lb.?

$$\frac{\text{Kilos.}}{\text{Kilos. in 1 lb.}} = \text{lbs. tallow} \therefore \frac{250{\cdot}0000}{\cdot 4536} = 551{\cdot}15 \text{ lbs.}$$

$$\text{£}11\ 17\text{s. } 4\text{d.} = 2848 \text{ pence. } \frac{\text{pence}}{\text{lbs. tallow}} = \frac{2848{\cdot}00}{551{\cdot}15} = 5{\cdot}17\text{d. Ans.}$$

$$8.\quad 24 - \sqrt{16} - (9+11)^2 = 24 - 4 - 400 = -380 \text{ Ans.}$$

9. Five Boilers with 4 furnaces in each, there are 2 lengths of bars, and 16 bars in each length, each bar weighs 40 lbs.; what would a full set cost at 7s. 3d. per cwt.?

boilers × furnaces × lengths × bars × weight in lbs. ÷ 112 × price

$$= 5 \times 4 \times 2 \times 16 \times \frac{40}{112} \times 7{\cdot}25 = \frac{5 \times 4 \times 2 \times 40 \times 7{\cdot}25}{7} = \overset{\text{£}}{82}\ \overset{\text{s.}}{17}\ \overset{\text{d.}}{1\tfrac{5}{7}}$$

10. What is the pressure per square inch, when the temperature is 82° Fah., and the barometer shews 28½ inches of Mercury ?

$$\textit{Rule.}\quad \frac{4907 \times h}{9057 + \text{temperature}} = \frac{4907 \times 28{\cdot}5}{9057 + 82} = 15{\cdot}302 \text{ lbs. Ans.}$$

11. A screw shaft is 21′ 9″ over all, and 11½″ diameter, the coupling flanges are 17½″ diameter, and 4″ thick, there are 5 holes in each coupling 2½″ diameter; what is the weight of the shaft ?

$$\frac{(d^2\ L + D^2\ l - d'^2\ l \times 5)\cdot 7854}{3{\cdot}6} =$$

$$\frac{11{\cdot}5^2 \times 253 + 17{\cdot}5 \times 8 - 2{\cdot}5^2 \times 8 \times 5) \times \cdot 7854}{3{\cdot}6}$$

21′ 9″ over all
8 = 4 × 2 = l Answer 3 tons. 9 cwts. 1 qr. 23·6597 lbs.

21 1
12

253 inches = L

12. A coal bunker is 24′ at the top, 21′ at the middle, and 16′ at the bottom, it is 18′ long, and 12′ high; how many tons coal will it hold at 45 cubic feet per ton?

$$\frac{24+(21\times 4)+16}{6} = 20{\cdot}667 = \text{mean breadth}$$

$$\frac{\text{Mean breadth}\times\text{length}\times\text{height}}{45} = \frac{20{\cdot}667\times 18\times 12}{45} = \begin{array}{c}\text{Ans.}\\ 99{\cdot}2 \text{ tons.}\end{array}$$

PAPER IV.

FIRST AND SECOND CLASS.

1. $\sqrt{(20+16)}-(4+7) = 6-11 = -5$ Answer.

2. What is the radius of a circle whose area is equal to that of a rectangle whose sides are 6863·7 by 574·5?

$$\text{radius} = \text{diameter} \div 2 = \sqrt{\left(\frac{6863{\cdot}7 \times 574{\cdot}5}{{\cdot}7854}\right)} \div 2 = 1120{\cdot}3 \text{ Ans.}$$

3. $\frac{7}{16}$ of one-9th part of 36.

$\frac{7}{16} \times \frac{1}{9} \times \frac{36}{1} = \frac{7}{4} = 1\frac{3}{4}$ Answer.

4. A balance weight of a crank weighs 14,000 lbs. the effective radius is 1·5 feet, and making 90 revolutions per minute, there are two bolts to hold it; what diameter must it be when the strain is not to exceed 5000 lbs per square inch of its section?

Formula. $\dfrac{R^2 d}{5870} =$ centrefugal force in tons

Where R = revolutions, d = 2 radius.

$$\therefore \frac{90 \times 90 \times 3}{5870} = \frac{90 \times 9 \times 3}{587} = 4{\cdot}14 \text{ nearly}$$

$$\text{And } \frac{14000 \times 4{\cdot}14}{5000 \times 2 \times {\cdot}7854} = \frac{4{\cdot}14}{5 \times {\cdot}1122} = 7{\cdot}38 = (\text{dia})^2$$

$\sqrt{(7{\cdot}38)} = 2{\cdot}7$ inches, nearly Answer.

Note. $d = 2r$.

5. A steamer runs the measured mile in 5 min. 10 sec. with the tide, and in 7 min 30 sec. against the tide; what is the ship's correct rate of sailing?

(5m. 40s. + 7m. 50s.) ÷ 2 = 6m. 45s. = 405 sec.

405 sec. : 3600 sec. : : 1 knot : 8·88 knots per hour Ans.

6. An engine counter has 6 counting wheels, and it stood at 005427 at the commencement of the voyage, you know that it has gone round twice, it now stands at 000729; how many miles has the ship gone, the pitch of the propeller being 21 feet?

$$\frac{(1000\,000 - 5427 + 2000\,000 + 729) \times 19}{6080} = 9360{\cdot}3 \text{ miles Ans.}$$

7. If the counter advance from 080374 to 628897 in 86 hours; what will it indicate in 380 hours?

$$86 : 380 :: (628897 - 80374) : 2423706{\cdot}3$$

$$(2423706 + 80374) - 2000\,000 = 504080 \text{ Answer.}$$

8. If you are continually blowing off at ·125 of the feed, and if the water in the boiler contain 11° of salt to the gallon; what was the saltness of the feed water?

$${\cdot}125 = \tfrac{1}{8} \qquad 8)\underline{11} \qquad \text{or } {\cdot}125 \times 11 = 1{\cdot}375$$

1·375 Answer.

9. A ship carried 1800 tons coals, with a consumption of 11 tons per day, and a speed of 8·4 knots per hour; she is now lengthened and fitted with compound engines, and carries 2200 tons, with a consumption of 10·8 tons, and the same speed as before; what quantity of coal is saved in a voyage of 7000 nautical miles?

$$7000 \div (8{\cdot}4 \times 24) = 34{\cdot}722 \text{ days on voyage.}$$

$$(11 - 10{\cdot}8) \times 34{\cdot}722 = 6{\cdot}9444 \text{ tons less consumed.}$$

$$(2200 - 1800 + 6{\cdot}9) = 406{\cdot}9 \text{ tons saved Answer.}$$

10. An engine is contracted for, to have 28 circular inches per N.H.P., but on her trial trip she works up to 4 times her N.H.P., she has 42" stroke and 20 lbs. mean effective pressure; how many revolutions should she make to fulfil her contract?

$${\cdot}7854 \times \text{circular inches} = \text{area in square inches.}$$

$$\frac{\text{N.H.P} \times 4}{\text{area} \times \text{pressure} \times \text{twice stroke}} = \frac{33000 \times 4}{21{\cdot}9912 \times 20 \times 7} = 42{\cdot}87 \text{ rev. Ans.}$$

11. The stays of a boiler bottom are to be fitted by cotters, the depth of cotter being 3 times the thickness, the diameter of stay 1⅞"; what size should the end be swelled out to so as to have uniform strength of bar?

Formula. $D = (1 + \frac{\cdot08}{n} + \frac{\cdot4}{\sqrt{n}})\,d$

Where D = size; d = diameter of stay; n = 4.

$\therefore\ (1 + \frac{\cdot08}{4} + \frac{\cdot4}{\sqrt{4}}) \times 1{\cdot}875 = 1{\cdot}22 \times 1{\cdot}875 = 2{\cdot}29$ Answer.

12. Find the N.H.P. of the engines you were with last, and the maximun strain on the crank pin ?

Say the diameter of L.P. is 68′, diameter of H.P. 32″, steam 60 lbs., crank pin 12″ diameter, and length 18″.

Formula. $(d^2 + D^2) \div 30$ = N.H.P.
$\cdot7854\ d^2\ p \div c\ l$ = maximum strain.

Where d = diameter H.P.; D = diameter L.P.; p = pressure; c = diameter crank; l = length crank.

$\therefore\ (32^2 + 68^2) \div 30 = 166{\cdot}433$ = N.H.P.
$(\cdot7854 \times 32^2 \times 60) \div (12 \times 18) = 223{\cdot}403$ lbs. Answer.

PAPER V.

FIRST AND SECOND CLASS.

1. $$\begin{array}{rcl} (264-143)^{\frac{1}{2}}+(8\times 6) & = & x \\ \sqrt{(121)}+\ \ 48 & = & x \\ 11\ +\ \ 48 & = & x \\ \text{Answer}\ \ \ 59 & = & x \end{array}$$

2. What is the sum of $\frac{4}{28}$ and $\frac{5}{18}$.

$\frac{4}{28} = \frac{1}{7}$; and the least common multiple of the denominators 7 and 18 is 126.

$$\therefore \frac{1}{7}+\frac{5}{18} = \frac{1\times 18}{7\times 18}+\frac{5\times 7}{18\times 7}$$

$$= \frac{18}{126}+\frac{35}{126} = \frac{18+35}{126} = \frac{53}{126} \text{ Answer.}$$

3. $\frac{7}{16}$ of one-11th part of 77

$$\frac{7}{16}\times\frac{1}{11}\times\frac{77}{1} = \frac{7}{16}\times\frac{7}{1} = \frac{49}{16} = 3{\cdot}06 \text{ Answer.}$$

Note. $11\div 11 = 1$, and $77\div 11 = 7$; hence, by cancelling we have as above.

4. Find the H.P. exerted by a pump in pumping out a tank 22 feet long, 16 feet broad, and 4 feet high, the top of which is 16 feet below the level of the sea; a cubic foot of sea water weighs 64 lbs., and 31000 lbs. of water raised 1 foot in 1 hour is equal to 1 H.P.; it took 5 hours to pump the tank out; 40 per cent. of the work was lost through non-efficiency.

$22\times 16\times 4\times 64 = 90112$ lbs. of water in tank.

Depth of centre of gravity of water in the tank $= 16+4\div 2 = 18$.

$90112\times 18 = 1622016 =$ units of work exerted in 5 hours.

$1622016\div 5 = 324403{\cdot}2 =$,, ,, 1 ,,

$324403{\cdot}2\div 31000 = 10{\cdot}464 =$ H.P. exerted.

40 per cent. $= 4{\cdot}186 =$ H.P. non-efficient.

$6{\cdot}278 =$ H.P. efficient.

5. The stays of a boiler are 14" apart, from centre to centre, and one of them breaks, thus throwing more strain on the 4 stays that surround the broken one, they are 1⅞ diameter, and the pressure is 70 lbs. per square inch; what extra strain per square inch will be on the stays if we allow ⅓ more than each had at first?

The formula for the strain on the stays of a boiler is

$$S = \frac{P D^2}{\cdot7854\, d^2}$$

$$\left.\begin{array}{lll} \text{Where } S & = & \text{strain per square inch section of stay} \\ P & = & \text{pressure per square inch on boiler} \end{array}\right\} \text{in lbs.}$$

$$\left.\begin{array}{lll} D & = & \text{distance stays are apart} \\ d & = & \text{diameter of stay} \end{array}\right\} \text{in inches.}$$

Now by the condition of the question, one-third of the strain found by the preceding formula must be added to it; hence we have

$$\text{Strain} = \frac{70\times14\times14}{\cdot7854\times\frac{15}{8}\times\frac{15}{8}} = \frac{70\times14\times14\times8\times8}{\cdot7854\times15\times15}$$

$$\text{By cancelling} = \frac{2\times14\times14\times8\times8}{\cdot1122\times3\times15} = 4968\cdot905$$

$$\begin{array}{rll} 3)4968\cdot905 & \text{lbs.;} & \text{strain at first} \\ 1656\cdot302 & ,, & \text{one-third added} \\ \hline 6625\cdot207 & ,, & \text{total strain.} \\ \hline \end{array}$$

Note. $1\frac{7}{8} = \frac{15}{8}$

6. *Formula* $\dfrac{6\cdot55\, d^3}{l} = D^2$

$$\left.\begin{array}{lll} \text{Where } d & = & \text{diameter of crank shaft} \\ D & = & \quad ,, \quad \text{cylinder} \end{array}\right\} \text{in inches.}$$

l = length of stroke; in feet.

A crank shaft is 14" diameter, length of stroke 4′ 6", pressure about 30 lbs.; what diameter of cylinder will suit that size of crank according to the above formula.

$$\frac{6\cdot55\times14^3}{4\cdot5} = 3994\cdot04 = D^2$$

SECOND CLASS.

EXERCISE 5.

1. $(67 - 63)^2 \div 8 + 2 - 17.$ Answer — 13.

2. $\dfrac{(24+12)^2}{(6+4)^2} - (6 \times 4) + 18 - 7.$ Answer — ·04.

3. A stay is 15″ apart, centre to centre, and it is eaten away to 1⅛″ diameter, the pressure is 20 lbs. per square inch; what is the strain per square inch section of the stay?

$$s = \frac{a^2\, p}{\cdot 7854\, d^2} = \frac{15 \times 15 \times 20 \times 8 \times 8}{\cdot 7854 \times 9 \times 9} = 4527 \text{ lbs. Answer.}$$

$1\tfrac{1}{8} = \tfrac{9}{8}$; $\tfrac{9}{8}$ inverted $= \tfrac{8}{9}$

4. What is the amount of wages— £
from 21st June to 20th December, at 14 per month.
,, 15th March to 18th December ,, 6 ,,
,, 28th October to 18th February ,, 6 ,,

Note.—Allow 30 days to the month.

days.		days.		£		£	s.	d.	
30	:	182	: :	14	:	84	18	8	
30	:	273	: :	6	:	54	12	0	
30	:	113	: :	6	:	22	12	0	
						162	2	8	Answer.

5. An Engineer has a bonus of £18 for coal economy, there were 84 tons left at 18s. per ton; what was his per centage on the value?

tons. s.		£ s.		per cent.		per cent.	
(84 × 18)	:	(18 × 20)	: :	100	:	23·8	Answer.

6. The diameter of the cylinder is 64 inches, the length of stroke 8 feet, revolutions per minute 66, and the pressure of steam per square inch 22·8 lbs; what is the horse power;

$$H.P. = \frac{\cdot 7854\, d^2\, p\, s\, r \times 2}{33000} = \frac{\cdot 7854 \times 64 \times 64 \times 22\cdot 8 \times 8 \times 66 \times 2}{33000}.$$

$$= \frac{\cdot 7854 \times 64 \times 64 \times 22\cdot 3 \times 3 \times 2 \times 2}{500} = 860\cdot 8687 \text{ Answer.}$$

7. The area of the boiler level is 120 square feet, a single acting donkey engine can pump up 17″ in the glass per hour, diameter of pump 4″, stroke 5″, revolutions per minute 100; what is the efficient stroke of the pump?

$$f = \frac{1728\ a\ h}{\cdot 7854\ d^2\ s\ r \times 60} = \frac{1728 \times 120 \times 17}{\cdot 7854 \times 4 \times 4 \times 5 \times 100 \times 60 \times 12}$$

$$= \frac{3 \times 17}{\cdot 2618 \times 5 \times 10 \times 5} = \cdot 779 \text{ of the stroke} = 3\cdot 895'' \text{ Ans.}$$

8. What is the per centage of strength of a single rivetted seam, diameter of rivets ⅞″, pitch 1¾″ and thickness of plate ⅜″?

Plate. $\left\{\frac{p-d}{p}\right\} \times 100.$ By Vulgar Fractions.

$$1\frac{3}{4} = \frac{7}{4} = \frac{14}{8}. \left\{\frac{\frac{7}{4}-\frac{7}{8}}{\frac{7}{4}}\right\} \times 100 = \left\{\frac{\frac{14-7}{8}}{\frac{14}{8}}\right\} \times 100$$

$$= \frac{7}{14} \times 100 = \tfrac{1}{2} \times 100 = 50 \text{ per cent. Answer.}$$

By Decimal Fractions.

$$1\tfrac{3}{4} = 1\cdot 75;\ \tfrac{7}{8} = \cdot 875$$

$$\left(\frac{1\cdot 75 - \cdot 875}{1\cdot 75}\right) \times 100 = \frac{\cdot 875}{1\cdot 75} \times 100 = \frac{1}{2} \times 100 = 50 \text{ per cent}$$

$$\text{Rivets} = \frac{\text{area} \times \text{No. rivets} \times 100}{p \times T} = \frac{\cdot 7854\ d^2 \times 1 \times 100}{p \times T}$$

By Vulgar Fractions.

$$= \frac{\cdot 7854 \times \frac{7}{8} \times \frac{7}{8} \times 1 \times 100}{\frac{7}{4} \times \frac{3}{8}}$$

$$= \frac{\cdot7854 \times 7 \times 7 \times 4 \times 8 \times 1 \times 100}{8 \times 8 \times 7 \times 3} = \cdot1309 \times 7 \times 100$$

$$= 91\cdot63 \text{ per cent. Answer.}$$

By Decimal Fractions.

$$\frac{\cdot7854 \times \cdot875 \times \cdot875 \times 1 \times 100}{1\cdot75 \times \cdot375} = 91\cdot63 \text{ per cent. Answer.}$$

9. How many bolts 1½" diameter are required for a cylinder cover 60" diameter, the pressure being 60 lbs, and the strain per square inch section of bolts is not to exceed 2000 lbs. ?

$$n = \frac{D^2 p}{d^2 s} = \frac{60 \times 60 \times 60 \times 2 \times 2}{2000 \times 3 \times 3} = 2 \times 2 \times 6 \times 2 = 48 \text{ bolts Ans.}$$

$1\frac{1}{2} = \frac{3}{2}$; $\frac{3}{2}$ inverted $= \frac{2}{3}$.

10. A coal bunker is 18 feet wide by 11 feet 9 inches high, and in 6 days a section of the bunker, 12 feet long was consumed; what was the consumption per day ?

$$\text{Tons per day} = \frac{l\,b\,h}{45 \times 6} = \frac{12 \times 18 \times 141}{45 \times 6 \times 12} = \frac{141}{15} = 9\cdot4. \text{ Ans.}$$

11′ 9′
12
141
12

45 cubic feet = 1 ton.

11. In a wheel and axle, the diameter of the barrel was 6" and that of the rope ⅞", the crank handle was 15" long, and the weight was 215 lbs.; what was the force exerted, allowing 12 per cent. for friction ?

$$\text{Force} = \frac{\frac{1}{2}\,(\text{barrel}+\text{rope}) \times \text{weight}}{\text{length of handle}} + 12 \text{ per cent.}$$

$$\frac{\frac{1}{2}\,(6\frac{7}{8}) \times 215}{15} = \frac{3\cdot4375 \times 215}{15} = \frac{3\cdot4375 \times 43}{3} = 49\cdot27083 \text{ lbs.}$$

$$(49\cdot27083 + 49\cdot27083 \times \tfrac{12}{100}) = 55\cdot18332 \text{ lbs. Answer.}$$

12. A slide valve is worked by a hooped spindle, the hoop surrounding the body of the valve ; the port of the valve is 20" wide, rectangular, and the recess is 4" deep, the exhaust port of the cylinder is 6¾" deep, and the steam port 2¾", the bars 1¾", internal cover ⅛", and lap 3" ; the valve is 1⅛" on each side of the ports, face of the valve is 1" thick, and the rest of the valve is ¾" thick ; find its weight if 3·9 cubic inches weigh 1 lb. ?

See the figure.

$PQ = MN - (MP + QN) = MN - MP \times 2$

$MN =$ (steam lap + steam port + bar) $\times 2 +$ exhaust port

$= (3 + 2\frac{3}{4} + 1\frac{3}{4}) \times 2 + 6\frac{3}{4} = 15 + 6\cdot75 = 21\cdot75$

$MP \times 2 =$ (steam lap + steam port + internal cover) $\times 2$

$= (3 + 2\frac{3}{4} + \frac{1}{8}) \times 2 = 11\cdot75$

$PQ = MN - MP \times 2 = 21\cdot75 - 11\cdot75 = 10\cdot00$ breadth of valve port.

ENDS OF FACE.

Length = width of valve port + distance on each side $= 20 + 1\frac{1}{2} + 1\frac{1}{2} = 23$

Cubic inches $= 23 \times 11\cdot75 \times 1 = 270\cdot25$.

SIDES OF FACE

Breadth of valve port + distance on each side $= 10 \times (1\frac{1}{2} + 1\frac{1}{2})$

$= 10 \times 3 = 30$

Cubic inches $= 10 \times 3 \times 1 = 30$

RECESS.

Length of walls $= \left\{(\text{width} + \text{twice thickness}) + \text{breadth valve port}\right\} \times 2$

$= \left\{(20 + \frac{3}{4} + \frac{3}{4}) + 10\right\} \times 2 = 63$

Depth of walls $= 4 + \frac{3}{4} - 1 = 3\cdot75$; *Thickness of walls* $= \cdot75$

Cubic inches $= 63 \times 3\cdot75 \times \cdot75 = 177\cdot1875$

Back = width × breadth × thickness $= 20 \times 10 \times \cdot75 = 150$

Answer $= (270\cdot25 + 30 + 177\cdot1875 + 150) \div 3\cdot9 = 160\cdot881$ lbs. Ans.

SECOND CLASS.

EXERCISE 6.

1. $125 \div 4 + 27 - 3\cdot4 \times 6\cdot2 = 31\cdot25 + 27 - 52\cdot08 = 6\cdot17$ Ans.

2. A sheet of lead is 16′ 3″ long, by 12′ 9″ broad, and $\frac{5}{16}$″ thick; what would it cost at 4d. per lb., if a cubic inch of lead weigh ·4126 of a lb.?

Length = 16′ 3″ = 195″; breadth = 12′ 9″ = 153″

Cost = cubic inches × weight of 1 cubic inch × price of 1 lb.

$$= \frac{195 \times 153 \times 5 \times \cdot4126 \times 4}{16} \qquad \text{Answer } \overset{\pounds}{64}\ \overset{\text{s.}}{2}\ \overset{\text{d.}}{3\cdot4}$$

3. If a piston be 43″ diameter, and assuming it to be 4¼″ thick throughout; what will it weigh if 3·9 cubic inches of cast iron weigh 1 lb?

$$w = \frac{\cdot7854\, d^2\, h}{3\cdot9} = \frac{\cdot7854 \times 43^2 \times 4\cdot25}{3\cdot9} = 1582\cdot58 \text{ lbs. Ans.}$$

4. What is the cost of wrought iron forging, weighing 16cwt. 3qrs. 14lbs., at 28s. 3d. per cwt.?

	lbs.		cwts.	qrs.	lbs.		s.	d.		£	s.	d.	
As	112	:	16	3	14	: :	28	3	:	23	16	8⅝.	Answer.

5. The travel of the slide is 9¼″, cover 3¼″ lead $\frac{1}{16}$″, and stroke of the piston 42″; how far is the piston from the end of the stroke when the steam is cut off?

$$\left\{\frac{c \times 2 + l}{t}\right\}^2 s = \left\{\frac{3\cdot25 \times 2 + \frac{1}{16}}{9\cdot25}\right\}^2 \times 42 = (\cdot7095)^2 \times 42$$

$$= 21\cdot14289 \text{ in. Ans.}$$

6. The steam pipe is 12 inches diameter, and goes inside the boiler, the part inside has slots 6 inches long and ¼ inch wide; how many slots must there be to make an area equal to double the sectional area of the pipe? and what are those slots for?

$$\text{Number of slots} = \frac{\text{area of pipe} \times 2}{\text{area of every slot}} = \frac{\cdot7854 \times 12 \times 12 \times 2}{6 \times \frac{1}{4}}$$

$$= \frac{\cdot7854 \times 12 \times 12 \times 2 \times 4}{6 \times 1} = \cdot7854 \times 2 \times 12 \times 2 \times 4 = \overset{\text{Ans.}}{150\cdot7968}$$

To Prevent Priming.

7. A T-headed piston rod of an oscillating engine whose dimensions are 12′ 6″ over all, and 8″ diameter, the head is 30″ long, 10″ wide, and 5″ deep; what is the weight of it? and make a sketch?

$$\frac{\cdot 7854\ d^2\ L + l\ b\ t}{3\cdot 6} = \frac{\cdot 7854 \times 8^2 \times 145 + 30 \times 10 \times 5}{3\cdot 6}$$

$$= \text{1ton 1cwt. 3qrs. } 5\cdot 2533\text{lbs. Answer.}$$

12′ 6″
    5

12 1
12

145

8. *Note.*—The pressure on the guide has the same proportion to the pressure on the piston as the length of the crank has to the length of connecting rod.

Question.—The piston is 48″ diameter, and the pressure is 29 lbs. per square inch, the length of the crank is 24″, and of the connecting rod is 8′ 4″, what is the strain per square inch section of the face of the cross head, the face being 12″ by 10″?

Make a sketch showing the position of the greatest strain.

$$s = \frac{\cdot 7854\ d^2\ p\ c}{l\ b\ r} = \frac{\cdot 7854 \times 48^2 \times 29 \times 24}{12 \times 10 \times 100} = 104\cdot 95457 \text{ lbs. Ans.}$$

$$r = 8'\ 4'' \times 12 = 100''$$

9. A safety valve 6″ diameter has a spiral spring 5″ diameter outside, and $\frac{7}{8}$″ thickness of steel; what is the pressure per square inch?

Formulæ. $\dfrac{8000\ S^3}{d}$ = Total weight.................. *A*

$$p = \frac{8000\ S^3}{\cdot 7854\ D^2\ d} \quad \text{..................................} \quad B$$

Where S = thickness of steel
d = diameter of spring from centre of steel to centre of steel
p = pressure per square inch
D = diameter of valve

5″ diameter spring — $\frac{7}{8}$ thickness of steel = d = $4\frac{1}{8}$

Hence from *B* we have as follows:—

$$d = 4\tfrac{1}{8} = \tfrac{33}{8}\ ;\ \tfrac{33}{8} \text{ inverted} = \tfrac{8}{33}.$$

$$\frac{8000\times7\times7\times7\times8}{{\cdot}7854\times6\times6\times8\times8\times8\times33} = \frac{125\times7\times7}{{\cdot}1122\times6\times6\times33} = 45{\cdot}95 \text{ lbs.}$$

10. You can see the horizon 8 statute miles off, what is the height of the eye ?

Formulæ. $\sqrt{(\frac{3}{2}\times\text{height, in feet})}$ = distance in miles ...... *A*

∴ height, in feet = (distance, in miles)$^2 \times \frac{2}{3}$ .... *B*

From *B* height = $8^2\times\frac{2}{3}$ = 42·66 feet. Answer.

11. The sectional area of a ship at the water level was 4821 square feet, her draught before taking in bunker coals was 19·7 feet aft and 19·4 ft. forward, and after coaling she drew 21 feet aft and 20·8 feet forward ; how many tons did she take in ?

The weight of coals taken in will be equal to the weight of water displaced, which is equal to the cubic feet of water displaced divided by the cubic feet of water in one ton.

Hence :—

$$\text{Tons taken in} = \frac{\text{area of water level}\times\text{depth ship sunk}}{\text{cubic feet water in one ton}} \quad \ldots\ldots \; A$$

$$\begin{array}{llr}
 & & \text{Draught} \\
\text{Before coaling} & \left\{\begin{array}{l}\text{Aft}\\ \text{Forward}\end{array}\right. & \begin{array}{r}19'{\cdot}7\\ 19{\cdot}\,4\end{array} \\
 & & \overline{2)39{\cdot}\,1} \\
 & & \overline{19{\cdot}55}
\end{array}
\left.\vphantom{\begin{array}{l}1\\1\\1\\1\\1\end{array}}\right\}
\text{After coaling}
\begin{array}{llr}
 & & \text{Draught} \\
 & \left\{\begin{array}{l}\text{Aft}\\ \text{Forward}\end{array}\right. & \begin{array}{r}21'{\cdot}0\\ 20{\cdot}\,8\end{array} \\
 & & \overline{2)41{\cdot}\,8}
\end{array}$$

Mean draught after coaling .... 20·90
Mean draught before coaling.................................. 19·55

Difference = depth the ship sunk .... 1·35

Hence from *A*, and remembering that there are 35 cubic feet of water in 1 ton, thus we have

$$\frac{4821\times1{\cdot}35}{35} = \frac{4821\times{\cdot}27}{7} = 185{\cdot}953 \text{ tons. Answer.}$$

12. A scale of iron is taken off, it weighs 5 oz., and it consists of 112 parts of iron and 48 of oxygen ; how much iron is in the scale ?

$$\begin{array}{r}\text{parts}\\ 112\\ 48\\ \hline 160\\ \hline\end{array} \qquad \begin{array}{rcrcrcr} \text{parts} & & \text{parts} & & \text{oz.} & & \text{oz.}\\ \text{As } 160 & : & 112 & :: & 5 & : & 3{\cdot}5. \text{ Answer.}\end{array}$$

13. The above scale was 7″ by 4″, and of uniform thickness ; what was its thickness ?

Volume = area × thickness .... *A*

$$\therefore \quad \text{Thickness} = \frac{\text{volume}}{\text{area}} \quad \text{...........................} \quad B$$

Now the volume of 1 lb. of iron = 3·6 cubic inches, and assuming the volume of 1 lb. of the scale to be the same, we have 5 oz. = $\frac{5}{16}$ of 1 lb., therefore the volume of the scale = $3{\cdot}6 \times \frac{5}{16}$

$$= \frac{{\cdot}9 \times 5}{4} = \frac{4{\cdot}5}{4} = 1{\cdot}125$$

And by the question, the area = 7×4 ; hence by *B*

$$\text{Thickness} = \frac{1{\cdot}125}{7 \times 4} = {\cdot}04017 \text{ of an inch. Answer.}$$

SECOND CLASS.

EXERCISE 7.

1. A ratchet wheel has 20 teeth, and the shaft wheel 56 teeth, each stroke of the lever takes 3 teeth of the ratchet, 10 pulls per minute; how long will it take to turn an engine from top to bottom centre?

2)56 shaft wheel

28 half shaft wheel
20

3)560

1,0)18,6·6667

18·66667 Answer 18 min. 40 sec.
60

40·00020

2. A boiler is to have 1·22 square feet per lb. of coal, the draught is to be caused by a fan; what will be the efficiency, and if the evaporative power of the fuel is 13 times its weight of water; what weight of steam will that be per lb. of coal?

Rule. Divide the square feet per lb. of coal by the same number +·5 if caused by chimney, but by +·3 if caused by fan or blast, and $\frac{11}{12}$ of the quotient will be the total efficiency nearly.

$1·22+·3 = 1·52$; 1·52)1·22(·8026

$\frac{·8026 \times 11}{12} = ·7357 =$ efficiency nearly.

$·7357 \times 13 = 9·5641$ lbs. of steam per lb. of coal.

3. A scale of iron rust has been taken off, whose weight is 5 oz., it consists of 112 parts of iron and 48 parts of oxygen; how much iron is there in the scale?

$$112+48 = 160. \quad \overset{\text{parts.}}{160} : \overset{\text{parts.}}{112} :: \overset{\text{oz.}}{5} : \overset{\text{oz.}}{3\cdot5} \text{ Answer.}$$

4. The above scale is 7" by 4", and of uniform thickness ; required its thickness ?

1 lb. of iron contains 3·6 cubic inches

$$\therefore\ 5 \text{ oz.} = \tfrac{5}{16} \text{ lb.} = \tfrac{5}{16}\times3\cdot6 = 1\cdot125 \text{ cubic inches.}$$

And by Art 9, *Formula D*, $h = \dfrac{v}{lb.} = \dfrac{1\cdot125}{7\times4} = \cdot040178$ inches.

5. A ship with a certain draught of water is sunk 3" by putting 37 tons into her ; what is the area of the water level ?

From Art. 9, *Formula A*, we have

$$l\,b = \frac{v}{h} = \frac{37\times35}{\frac{3}{12}} = \frac{37\times35\times12}{3} = 37\times35\times4 = 5180 \text{ sq. ft.}$$

Notes.—35 cubic feet of sea water weigh 1 ton. $\frac{3}{12}$ inverted $= \frac{12}{3}$.

6. The boiler contained 55 tons of fresh water on starting on a voyage, by some leak the water in the hotwell is $\frac{1}{8}$ of the saltness of the sea; how many tons of water must have evaporated during the voyage if at its end the water in the boiler is $2\frac{1}{2}$ times the saltness of the sea, there having been no blow off.

$$\text{Tons evaporated} = \frac{55\times2\cdot5}{\frac{1}{8}} = 55\times2\cdot5\times8 = 1100. \text{ Answer.}$$

Note.—$\frac{1}{8}$ inverted $= \frac{8}{1}$.

7. $(289-240)^{\frac{1}{2}}+7\times45 = \sqrt{49}+315 = 7+315 = 322$ Ans.

8. An engine counter has 6 counting wheels and stood at 000 743 6 at the commencement of the voyage, and you know it has gone once round, it now stands at 000 121 ; how many knots has the ship gone, the pitch being 18 feet ?

$$\left.\frac{1\,000\,000+(1\,000\,000-7\,436)+121}{6080}\right\}\frac{\times18}{} = 5899\cdot4 \text{ knots. Ans.}$$

9. There are 3 cross bunkers in a ship, the coals in the centre bunker do not alter the trim of the ship, but coals in the other two bunkers will, unless they be properly proportioned, the distance between the centres of the middle and forward bunker is 34 feet, and the distance between the centres of middle and after bunker is 76 feet, 400 tons of coal have to go into these two bunkers so that the ship may keep her trim ; how many tons must go in each of them ?

See question 7, page 127.

Rules.

$$\text{Coal aft} = \frac{\text{total coal} \times \text{distance from middle to forward}}{\text{total distance}} \quad \ldots A$$

$$\text{Coal forward} = \text{total coal} - \text{coal in aft bunker} \quad \ldots\ldots\ldots\ldots B$$

$$\text{By } A. \quad \frac{400 \times 34}{110} = 123{\cdot}636363 \text{ tons.}$$

By *B*.

	tons
Total coals......	400
Coals aft.........	123·636363
Coals forward...	276·363637

10. A paddle wheel is 29 feet from centre to centre of float, it makes 20 revolutions per minute, the ship makes 14 knots per hour ; what is the amount and per centage of slip ?

$$\frac{3{\cdot}1416\, d\, r \times 60}{6080} = \frac{3{\cdot}1416 \times 29 \times 20 \times 60}{6080} = 17{\cdot}98 \text{ rate of wheel}$$

17·98 : 3·98 : : 100 : 22·1 per centage of slip

17·98 rate of wheel
14·00 rate of ship

3·98 amount of slip

11. A steamer runs the measured mile in 5 minutes 12 seconds with the tide, and in 7 minutes 42 seconds against the tide ; what was her correct rate of sailing ?

$\{(5\text{m. } 12\text{s.}) + (7\text{m. } 42\text{s.})\} \div 2 = 387\text{sec}$ 387 : 3600 : : 1 : 9.302

9·302 miles. Answer.

12. You can see the horizon 9 statute miles from you ; find the height of your eye ?

Formulæ.

$$\sqrt{(\text{height in feet} \times 1{\cdot}5)} = \text{distance in miles} \quad \ldots\ldots\ldots\ldots A$$

$$\therefore \quad \text{height in feet} = \frac{(\text{distance in miles})^2}{1{\cdot}5} \quad \ldots\ldots\ldots\ldots B$$

∴ By *B*. height $= 9^2 \div 1{\cdot}5 = 54$ feet. Answer.

13. An inverted cylinder, the length of stroke is 44″, length of connecting rod 7′ 10″, the piston is 19″ inches from the bottom of the cylinder; what is the distance from the centre of the cross head to the centre of the crank shaft?

Stroke....................	44″
Half stroke..............	22
Piston from bottom ...	19
Cross head down	3

Connecting rod.........	7′	10″
Cross head down......	0	3
Answer..................	7	7

14. The length of the connecting rod is 7′ 2″, the piston rod is 70″ from the collar to the centre of the crosshead, the piston is $4\frac{1}{8}$″ thick, length of stroke 44′, the cover is $1\frac{7}{8}$″ into the cylinder, clearance is $\frac{3}{4}$″; what is the length from the top of the cylinder to the centre of the shaft?

Length $= 7' \, 2'' + 5' \, 10'' + 4\tfrac{1}{8}'' + 1' \, 10'' + 1\tfrac{7}{8}'' + \tfrac{3}{4}'' = 15' \, 4\tfrac{3}{4}''$. Ans.

Note.—$44'' \div 2 = 22''$ 1′ 10″.

SECOND CLASS.

EXERCISE 8.

1. A ship steams 2183 miles in 145 hours : what was her speed per hour ?

$$2183 \div 145 \;=\; 15{\cdot}055 \text{ knots per hour. Answer.}$$

2. A blow-off cock on the bottom of a boiler is 14 feet below the level of the sea, and 9 feet below the water level in the boiler ; what pressure per square inch would be required to blow the brine out ?

$$2{\cdot}305)14.000(6{\cdot}073 \text{ lbs. Answer.}$$

3. If 1 cwt. 3 qrs. 14 lbs. bolts and nuts cost £1 16s. 9d. ; what is that per lb. ?

$$\begin{array}{ccccccc} \text{cwts. qrs. lbs.} & & \text{lb.} & & \text{£ s. d.} & & \text{d.} \\ 1\;\;3\;\;14 & : & 1 & : & 1\;16\;9 & : & 2{\cdot}1. \text{ Answer.} \end{array}$$

4. Find the weight of the rim of a fly wheel ; whose outer diameter is 9′ 6″, inner diameter 7′ 5″, and thickness 7″, if ·257 cubic inches = 1 lb. ?

$$w \;=\; \frac{{\cdot}7854(D^2 - d^2)h \times {\cdot}257}{2240} \;=\; \frac{{\cdot}7854(114^2 - 89^2) \times 7 \times {\cdot}257}{2240}$$

$$= 3{\cdot}201 \text{ tons. Answer.}$$

5. A Whitworth thread on a bolt of 1¼″ diameter has a strain of 1200 lbs. per square inch of section ; find the actual strain on the bolt ?

$$\textit{Rule.}\;\left(\frac{\text{8ths} \times \text{8ths} - 1}{100}\right) \text{strain} \;=\; \left(\frac{10 \times 9}{100}\right) \times 1200 \;=\; 90 \times 12$$

$$= 1080 \text{ lbs. Answer.}$$

$$1\tfrac{1}{4}'' \;=\; \tfrac{10}{8}.$$

6. The feed water is 4·2 oz. of salt to the gallon, and the density of the water in the boiler is not to exceed 9·5 oz. ; what proportion of the feed requires to be blown off ?

$$\begin{array}{ccccccc} \text{oz. salt} & & \text{oz. salt} & & \text{gall.} & & \text{gall.} \\ 9{\cdot}5 & : & 4{\cdot}2 & : & 1 & : & {\cdot}44 \text{ blown off. Answer.} \end{array}$$

7. If 30 circular inches indicate one N.H.P., what is the mean effective pressure per square inch required to indicate 3½ times the N.H.P. if the piston run 380 feet per minute ?

$$\frac{33000 \times \text{times N.H.P.}}{\cdot 7854 \times \text{cir. inch} \times \text{feet run}} = \frac{33000 \times 3 \cdot 5}{\cdot 7854 \times 30 \times 380}$$

$$= \frac{110 \times 3 \cdot 5}{\cdot 7854 \times 38} = 12 \cdot 9 \text{ lbs. Ans.}$$

8. The sea water has 4·6 oz. salt to the gallon, and the hotwell has ·25 oz. to the gallon ; at what rate are the condenser tubes leaking in lbs. of steam ?

oz. oz. gall. galls.
·25 : 4·6 : : 1 : 18·4 in the hot well of which 1 gall. is salt, leaving 17·4 galls. fresh ; each gallon of fresh water weighs 10 lbs ; hence 17·4 × 10 = 174 lbs. Answer.

9. The area of the water level of a steamer is 4000 square feet ; what will be her extra draft when 100 tons more weight are put into her ?

$$\text{Cubic feet} = l\,b\,h \;\therefore\; h = \frac{\text{cubic feet}}{l\,b} = \frac{35 \times 100}{4000}$$

$$= \tfrac{7}{8} \text{ of a foot} = 10\tfrac{1}{2} \text{ inches. Ans.}$$

Note.—35 cubic feet of sea water weigh 1 ton.

10. Two cylinders, 30″ and 58″ inches diameter respectively, give 160 N.H.P. ; how many circular inches is that per N.H.P. ? And what is the ratio of the cylinders ?

$$\frac{30^2 + 58^2}{160} = \frac{900 + 3364}{160} = 26 \cdot 65 \text{ circular inches. Answer.}$$

$$\text{Ratio} = \frac{58^2}{30^2} = \frac{3364}{900} = 3 \cdot 738. \text{ Or; ratio} = \frac{30^2}{58^2} = \frac{900}{3364} = \cdot 268$$

Definitions.—The *ratio* of one quantity to another is the number of times that the former contains the latter.

A *proportion* consists of two equal ratios.

Thus $\frac{6}{3}$ and $\frac{8}{4}$ are equal ratios, for they are each = 2 ; hence $\frac{6}{3} = \frac{8}{4}$ is a proportion. This proportion is often expressed thus :—

6 : 3 : : 8 : 4

11. A paddle wheel is 29 feet from centre of float to centre of float, and makes 20 revolutions per minute ; how many knots will the ship go per hour, allowing 16 per cent. for slip, and 6080 feet equal to 1 knot ?

$$\frac{3{\cdot}1416\,dr \times 60 \times 84}{6080 \times 100}$$

100 — 16 = 84. Hence the rate of the ship is 84 per cent. of the rate of the wheel.

$$\frac{3{\cdot}1416 \times 29 \times 20 \times 60 \times 84}{6080 \qquad \times 100} = \frac{3{\cdot}1416 \times 29 \times 2 \times 6 \times 84}{6080} = 15{\cdot}104 \text{ knots}$$

12. If the piston travel 420 feet per minute, and the diagram indicate 18 lbs. mean pressure throughout the stroke, and 32 circular inches = 1 N.H.P.; how many N.H.P. will be indicated?

$$\frac{{\cdot}7854 \times 32 \times 18 \times 420}{33000} = \frac{{\cdot}0714 \times 32 \times 6 \times 42}{100} = 5{\cdot}757696 \text{ N.H.P.}$$

13. The stays of a boiler, at the smallest part, are 1⅛" diameter, and 16" apart, centre to centre, the government allowance is 5000 lbs. strain per square inch section of the stay; what should the safety valve be loaded at per square inch; and what would the weight be on a 4" valve?

$$p = \frac{{\cdot}7854\,d^2 s}{D^2} = \frac{{\cdot}7854 \times 9 \times 9 \times 5000}{16 \times 16 \times 8 \times 8} = 19{\cdot}41 \text{ lbs. Ans.}$$

$$1\tfrac{1}{8}'' = \tfrac{9}{8}'' \quad w = {\cdot}7854 d'^2 p = {\cdot}7854 \times 4^2 \times 19{\cdot}41 = 243{\cdot}9138 \text{ lbs.}$$

14. A rectangular lever is 7½" deep and 2" thick, and it is broken by by a weight of 2000 lbs. placed 84" from the point of fracture; what was the strain per square inch at the broken part?

Rule.

$$\frac{\text{Strain} \times B \times D \times D}{6} = w \times l$$

$$\therefore \text{Strain} = \frac{6 \times w \times l}{B \times D \times D} = \frac{6 \times 2000 \times 84}{2 \times 7{\cdot}5 \times 7{\cdot}5} = 8960 \text{ lbs. Ans.}$$

FIRST CLASS.

EXERCISE 1.

1. 675 is to what number as 4 is to 9 ?

4 : 9 : : 675 : 1518·75. Answer.

2. Find the value of £20·59 ?

$$\begin{array}{r} 20{\cdot}59 \\ 20 \\ \hline 11{\cdot}80 \\ 12 \\ \hline 9{\cdot}6 \\ \hline \end{array}$$

	£	s.	d.
Answer	20	11	9·6

3. Express the sum of ·525 and ·625 as a vulgar fraction ?

$$\begin{array}{r} {\cdot}525 \\ {\cdot}625 \\ \hline 1{\cdot}150 \\ \hline \end{array} = 1\tfrac{150}{1000} = 1\tfrac{3}{20}. \text{ Answer.}$$

4. $(340-16)^{\frac{1}{2}}+2\times 6 = \sqrt{324}+12 = 18+12 = 30$ Ans.

5. A compound engine has a steam receiver round the high pressure cylinder equal in diameter to that of the low pressure cylinder, and the steam chest for slide valves is between the cylinders, distance between the centres of cylinders 84″, diameter of L.P. cylinder is 50″, and depth 63″, how many square feet of felting will be required to cover it ?

$$\frac{(3{\cdot}1416\ d+\text{distance}\times 2)\times\text{depth}}{144} = \frac{(3{\cdot}1416\times 50+84\times 2)\times 63}{144}$$

$$= 142{\cdot}2225 \text{ square feet. Answer.}$$

6. The topmast of a ship is 81 feet above the level of the sea when upright, but when fore and aft sails are set she heels over until the topmast is only 72 feet above the sea level ; the diameter of the valve is 4·5 inches and is loaded to 520 lbs ; what will she blow off at when heeling over at this angle ?

$$\frac{h\ w}{{\cdot}7854\ d^2\ H} = \frac{72\times 520}{{\cdot}7854\times 4{\cdot}5\times 4{\cdot}5\times 81} = \frac{8\times 104}{{\cdot}7854\times{\cdot}9\times 4{\cdot}5\times 9}$$

$$= 29{\cdot}06 \text{ lbs. Answer.}$$

7. *Formula.*

$$S = \frac{5{\cdot}1\ W a}{d^3} = \frac{5{\cdot}1 \times {\cdot}7854 D^2\ p\ l}{d^3}$$

Where S = strain per square inch section of shaft
W = weight of leverage (= a)
d = diameter of shaft
D = diameter of piston
p = pressure of steam
l = length of crank

Question.—The piston is 93″ diameter, effective pressure of the steam 45 lbs., length of the crank 21″, and diameter of the shaft 16″. Is the shaft strong enough? and what is the strain per square inch of section?

$$\frac{5{\cdot}1 \times {\cdot}7854 \times 93 \times 93 \times 45 \times 21}{16 \times 16 \times 16} = 7992{\cdot}79 \text{ lb. Answer.}$$

The shaft is not strong enough; its diameter should be increased until the strain per square inch of section does not exceed 5000 lbs.

8. Four boilers with two furnances each, the diameter of each fire-grate is 2′ 10″; how many tons of coal will be consumed per day? and how many H.P. will be indicated?

Allow 2·5 lbs. coal burnt per I.H.P. per hour; and allow 1 ton per day for every foot diameter of fire grate.

$$\overset{\text{boilers.}}{4} \times \overset{\text{fur.}}{2} = \overset{\text{furnaces.}}{8}; \quad \overset{\text{dia.}}{(2'\,10'')} \times \overset{\text{fur.}}{8} = 22\tfrac{2}{3} \text{ tons.}$$

$$\overset{\text{lbs.}}{2{\cdot}5} \times \overset{\text{hours}}{24} = \overset{\text{lbs.}}{60} \text{ burnt per I.H.P. per day}$$

$$\frac{2240 \times 22\tfrac{2}{3}}{60} = 846{\cdot}22 \text{ I·H·P.}$$

9. An engine of 826 I.H.P. uses 21 lbs. of steam per hour; one air pump, single acting, 20″ diameter, 19″ stroke, and making 50 revolutions per minute; how many inches of the stroke will be full?

$$f = \frac{1728\ v}{{\cdot}7854\ d^2\ s\ n \times 60}$$

Now the water from the steam when condensed weighs the same as the steam did, and 1 cubic foot of fresh water weighs 62·5 lbs.; hence for v in the formula substitute $826 \times 21 \div 62{\cdot}5$ and we have

$$f = \frac{1728 \times 826 \times 21}{{\cdot}7854 \times 20 \times 20 \times 19 \times 50 \times 60 \times 62{\cdot}5}$$

$$= \frac{144 \times 59 \times 7}{\cdot 0374 \times 20 \times 10 \times 19 \times 50 \times 60 \times 62\cdot 5}$$

$$= \cdot 0268 \text{ fraction of stroke}$$

$$\cdot 0268 \times 19 = \cdot 5092 = \tfrac{1}{2} \text{ inch nearly. Answer.}$$

10. The steam guage shews 45 lbs., and it is carried for 14" of the stroke, the length of the stroke being 30", and the mean effective pressure 40 lbs. ; what is the co-efficient of efficiency ?

$$c = \frac{\text{mean pressure} \times \text{length of stroke}}{\text{gross pressure} \times (\text{length of admission} + \text{clearance})}$$

$$= \frac{40 \times 30}{60 \times 14} = 1\tfrac{3}{7}. \text{ Answer.}$$

11. If the loss by blowing off be ·12 of the fall used, and the temperature of the steam 320", and of the feed 110" ; what should the boiler be at above the feed density ?

$$n = \frac{T - t}{l(1115 + \cdot 3T - t)} + 1 = \frac{320 - 110}{\cdot 12(1115 + \cdot 3 \times 320 - 110)} + 1$$

$$= 2\cdot 59. \text{ Answer.}$$

12. If 26 lbs. of water at 110° Fahrenheit be added to 46 lbs. at 198° Fahrenheit, what will the resulting temperature be ?

$$\frac{26 \times 110 + 46 \times 198}{26 + 46} = \frac{11968}{72} = 166\tfrac{2}{9}^{\circ}. \text{ Answer.}$$

FIRST CLASS.

EXERCISE 2.

1. If 454 tons of Welch coal in the bunkers be sufficient for a voyage of 2900 miles, and Lancashire coal is for space in the proportion of 46 : 40, and is inferior in quality as 8·7 : 10·5; what distance will the bunkers carry her if filled with Lancashire coal?

$$\begin{array}{lllll} & & & \text{miles.} & \text{miles.} \\ 46 : 40 & :: & 2900 & : & 2089.44. \text{ Answer.} \\ 10{\cdot}5 : 8{\cdot}7 & & & & \end{array}$$

2. What pressure is allowed on a plate in the combustion chamber when the thickness of plate is $\frac{7}{16}''$, and the stays are 16" apart?

Formula. $$B = \frac{60(T+1)^2}{S-6}$$

Where B = boiler pressure; in lbs.
T = thickness of plate; in 16ths
S = surface = square of distance apart

$$\frac{60\times(7\times1)^2}{16^2-6} = \frac{60\times8\times8}{250} = \frac{6\times64}{25} = 15{\cdot}36 \text{ lb. Ans.}$$

3. And what would be the smallest diameter of stay in this case?

$$d = \sqrt{\left(\frac{S^2\,p}{{\cdot}7854\ s}\right)} = \sqrt{\left(\frac{16^2\times15{\cdot}36}{{\cdot}7854\times5000}\right)} = 1{\cdot}0006$$
$$= 1 \text{ inch nearly. Answer.}$$

4. What degree of Fahrenheit will correspond to 129° Centigrade; Cent. being marked 0° at freezing, and 100° at boiling point?

$$C\frac{9}{5}+32 = \frac{129\times9}{5}+32 = 264{\cdot}2 \text{ Fahrenheit. Answer.}$$

5. Three years ago wages were at £14 per month, and were then increased by 11 per cent.; it is now proposed to reduce them by 14 per cent.; what will be the new rate of wages?

$$\overset{\pounds}{14} + \frac{14\times11}{100} = \overset{\pounds}{14}+\overset{\pounds}{1{\cdot}54} = \overset{\pounds}{15{\cdot}54}$$

$$\overset{\pounds}{15{\cdot}54} - \frac{15{\cdot}54 \times 14}{100} = \overset{\pounds}{15{\cdot}54} - \overset{\pounds}{2{\cdot}1756} = \overset{\pounds}{13{\cdot}3644}$$

$$= \overset{\pounds}{13}\ \ \overset{s.}{7}\ \ \overset{d.}{3\tfrac{1}{4}{\cdot}844} \text{ Answer.}$$

6. The water in the hotwell is at 112°, and the vacuum in the condenser is 11½ lbs. : but by some accident the temperature of the water in the hot well rises to 154° ; what will the vacuum be ?

$$\textit{Rule.} \quad \frac{(T - t)\ T - 50)\ (t - 50)}{100000} = \text{loss of vacuum}$$

$$\frac{(154 - 112)\ (154 - 50)\ (112 - 50}{100\ 000} = \frac{42 \times 104 \times 52}{100\ 000} = 2{\cdot}70816$$

$$11{\cdot}5 - 1{\cdot}70816 = 8{\cdot}79184 \text{ lbs. new vacuum. Answer.}$$

7. If when the engines are making 41 revolutions, the mean effective pressure of the steam be 27lbs. ; how many revolutions will the engine make when the vacuum shews 1½ lbs. less with the same cut off of the steam ?

$$\begin{array}{l} \text{lbs.} \\ 27{\cdot}0 \\ \underline{\ \ 1{\cdot}5} \\ \underline{25{\cdot}5} \end{array} \qquad \overset{\text{lbs.}}{27} : \overset{\text{lbs.}}{25{\cdot}5} :: \overset{\text{rev.}}{41^2} : \overset{\text{rev.}}{x^2}$$

$$\therefore\ x = \sqrt{\left(\frac{25{\cdot}5 \times 41^2}{27}\right)} = 39{\cdot}84 \text{ rev. Answer.}$$

8. The square of the diameter of the funnel in feet is equal to the whole width of the fire grate ; the fire bars are 5 feet 9 inches long ; how many square feet of fire grate surface are there to 1 square foot of funnel section ?

Area of fire grate $= l\,w = l\,d^2$

Area of section of funnel $= {\cdot}7854\ d^2$

$$\therefore\ \frac{l\,d^2}{{\cdot}7854\ d^2} = \frac{l}{{\cdot}7854} = \frac{5{\cdot}75}{{\cdot}7854} = 7{\cdot}321 \text{ feet. Answer.}$$

9. Make a sketch of half a thrust block from the following, and find its weight when 1 cubic inch = ·3 of a lb. There are 9 collars, each 1¼″ thick, with $1\frac{1}{8}''$ space between, diameter of shaft 9″, of collars 11″, of seat 13″, and of flanges 15″, and the flanges are 1¼″ thick ?

$$\begin{array}{lcl} 1\tfrac{1}{4}'' \times 9 & = & 11\tfrac{1}{4} \text{ collars} \\ 1\tfrac{1}{8} \times 10 & = & \underline{11\tfrac{2}{8} \text{ spaces}} \\ & & \underline{22\tfrac{1}{2} \text{ seat}} \end{array} \qquad 1\tfrac{1}{4} \times 2 = 2\tfrac{1}{4} \text{ flanges}$$

Volume × weight of 1 cubic inch =

$$\cdot 7854\Big\{\overset{\text{seat shaft}}{(18^2-9^2)\times 22\cdot 5}+\overset{\text{flange shaft}}{(15^2-9^2)\times 2\cdot 25}-\overset{\text{collar shaft}}{(11^2-9^2)\times 11\cdot 25}\Big\}\times\cdot 8$$

$$= 445\cdot 3218 \text{ lbs. Answer.}$$

10. What is the value of $\frac{4}{9}$ of $\frac{3}{8}$ of 68 ?

$$\tfrac{4}{9}\times\tfrac{3}{8}\times\frac{68}{1} = \frac{21}{2} = 10\tfrac{1}{2}. \text{ Answer.}$$

11. A beam of 11 cwts. rests on 2 supports *A* and *B* 14′ apart, a weight of 4 tons is placed 7′ from *B*, and another of 7 tons at 6′ from *A* ; what share of these weights will *A* and *B* support ? See Figure.

W =	7 tons	w =	4 tons	AB	=	14′
	20 cwts.		20 cwts.	AW	=	6
	140 cwts.		80 cwts.	BW	=	8

Suppose the end of the beam at *A* be suspended by a force P acting upwards, and at first do not consider the weight of the beam ; then we have

$$\text{Force } P\times\text{distance } A\,B = \text{weight } W\times\text{distance } W\,B + \text{weight } W\times\text{distance } W\,B$$

$$\text{Or } P\times 14 = 140\times 8+80\times 7$$

$$\therefore\quad P = \frac{1120+560}{14} = 120 \text{ cwts.}$$

$P+\frac{1}{2}$ weight of beam $= 120+5\frac{1}{2} = 125\frac{1}{2}$ cwts = weight on *A*

Total weight — weight on *A* = weight on *B*

Or $W+w+$beam—weight on $A = 140+80+11-125\frac{1}{2} = 105\frac{1}{2}$ cwts.

$$\left.\begin{array}{r}\text{Or 6 tons } 5\frac{1}{2} \text{ cwts. on } A\\ \text{5 tons } 5\frac{1}{2} \text{ cwts. on } B\end{array}\right\}\text{ Answers.}$$

12. Find the thermal units of heat in an engine of the following dimensions ; diameter of cylinder 70″, stroke 35″, revolutions per minute 60, mean pressure 38 lbs. ; and find the coals burnt per hour, and how much per I.H.P. per day ?

$$\text{Thermal units} = \frac{\text{Units of work}}{\text{Joule's equivalent of heat}}$$

$$= \frac{\cdot 7854\times 70^2\times 38\times 6\times 60}{772} = 78195\cdot 4$$

Note.—1 lb. of good coal gives about 800 thermal units at the piston ; hence

8,00(681,95·4 thermal units

85·24 lbs. coal per minute
60 minutes = 1 hour

5114·40 lbs. coal per hour

$$H\,P\cdot = \frac{\cdot 7854 \times 70 \times 70 \times 38 \times 6 \times 60}{33000} = \cdot 0714 \times 7 \times 7 \times 38 \times 2 \times 6$$

$= 1595{\cdot}3616$

$5114{\cdot}4 \div 1595{\cdot}4 = 3{\cdot}206$ lbs. coal per H.P per hour

$3{\cdot}206 \times 24 = 76{\cdot}944$ lbs. coal per I.H.P. per day

FIRST CLASS.

EXERCISE 3.

1. $\sqrt{(30+34)} - (3+3) = \sqrt{64} - 6 = 8 - 6 = 2$. Ans.

2. What is the radius of a circle whose area is equal to that of a rectangle whose side are 7953·7 and 674·3 ?

$$r = \frac{d}{2} = \tfrac{1}{2}\sqrt{\left(\frac{a}{\cdot 7854}\right)} = \tfrac{1}{2}\sqrt{\left(\frac{7963{\cdot}7 \times 674{\cdot}3}{\cdot 7854}\right)} = 1307{\cdot}4$$

3. Five boilers with 4 furnaces in each; there are 2 lengths of bars and 17 bars in each length, each bar weighing 42 lbs.; what would a full set cost at 7s. 6d. per cwt ?

$$\frac{\text{Boilers} \times \text{furnaces} \times \text{lengths} \times \text{bars} \times \text{weight} \times \text{price}}{112} =$$

$$\frac{5 \times 4 \times 2 \times 17 \times 42 \times 7{\cdot}5}{112} = \text{£95 12s. 6d. Answer.}$$

4. An engine counter has 6 counting wheels, and it stood at 007436 at the commencement of the voyage, and you know that it has gone round twice, it now stands at 000624, how many knots has the ship gone, the pitch being 21 feet ?

$$\left\{\frac{2\,000\,000 + (1\,000\,000 - 007\,346) + 624}{6080}\right\} \times 21 = 10338{\cdot}3 \text{ knots.}$$

5. A screw shaft is 20′ 9″ over all, and 11″ diameter, the coupling flanges are 17″ diameter and 4″ thick, there are 5 holes in each coupling 2½″ diameter ; what is the weight of the shaft ?

$$\cdot 7854\left(\frac{d^2\,L + D^2\,l - d'^2\,l \times 5}{3{\cdot}6}\right)$$

$$= \cdot 7854\frac{(11^2 \times 241 + 17^2 \times 8 - 2{\cdot}5^2 \times 8 \times 5)}{3{\cdot}6}$$

20′ 9″
— 8 = 4 × 2 = 3 tons 0 cwts. 3 qrs. 7·818 lbs. Ans.

20 1
12

241

6. A coal bunker is 32′ at the top, 29′ in the middle, and 24′ at the bottom; it is 30′ long and 20′ high; how many tons will it hold at 45 cubic feet per ton?

$$\begin{array}{rcr} & & 32' \\ 29\times 4 & = & 116 \\ & & 24 \\ \hline & 6) & 172 \\ \hline & & 28{\cdot}667 \end{array}$$

$$\text{Tons} = \frac{l\,b\,h}{45} = \frac{30\times 28{\cdot}667\times 20}{45}$$

$$= 382{\cdot}22667 \text{ tons. Answer.}$$

7. In altering the pitch of a screw propeller it is found that when the mean effective pressure of the indicator diagram is not altered the product of the pitch by the square of the knots per hour is not altered.

If the pitch be altered as under what will be the speed of the vessel, the diagram remaining the same?

Old pitch 14 feet, speed 8 knots, new pitch 13 feet.

$$\begin{array}{ccccccc} \text{As new pitch} & : & \text{old pitch} & :: & \text{old knots} & : & \text{new knots} \\ 13 & : & 14 & :: & 8^2 & : & x^2 \end{array}$$

$$\therefore \text{ New knots} = \sqrt{\left(\frac{14\times 64}{13}\right)} = 8{\cdot}3 \text{ knots. Answer.}$$

8. The pressure forcing a slide valve upon a cylinder face depends a great deal upon the state of the surface; but in a common slide valve it is never far from equal to the difference between the pressures per square inch in the exhaust passage, calculated for an area equal to the sum of the area of the port in the valve added to the area of the steam port.

Question.—The port of the slide valve is 9 inches by 28 inches, the port of the cylinder 1½ inches by 28 inches, the steam guage shewed 36 lbs., and the back pressure is 4 lbs.; find the pressure forcing the slide upon the cylinder?

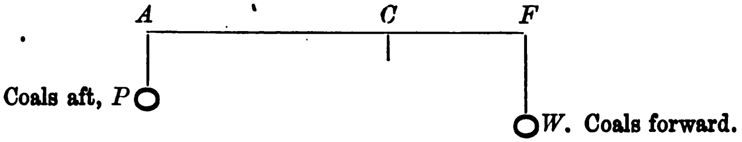
$$\begin{array}{lr} & \text{lbs.} \\ \text{Steam} & 36 \\ \text{Atmos.} & 15 \\ \hline \text{Gross} & 51 \\ \text{Back} & 4 \\ \hline \text{Effective} & 47 \\ \hline \end{array}$$

$$\begin{array}{lcr} \text{Valve port } 28\times 9 & = & 252 \\ \text{Steam port } 28\times 15 & = & 42 \\ \hline & & 294 \\ \hline \end{array}$$

$$294\times 47 = 13818 \text{ lbs.} = \begin{array}{cccc} \text{tons} & \text{cwts.} & \text{qrs.} & \text{lbs.} \\ 6 & 3 & 1 & 14 \end{array}$$

9. There are 3 cross bunkers in a ship, the coals in the centre do not alter the trim of the ship, but the coals in the other two will, unless properly proportioned between them, the forward bunker is 34 feet from

its centre to the centre of the middle one, while the after bunker is 76 feet from the same centre, you have to put 400 tons of coal in these two bunkers so that the ship may keep her trim; how many tons must go in each?



$$P = \frac{(P+W)\times CF}{CF+CA} = \frac{400\times 34}{110} = \frac{40\times 34}{11} = 123{\cdot}64$$

Total coals 400·00 tons
Coals aft 123·64 }
Coals forward 276·36 } Answers.

10. A pair of common engines of 180 N.H.P. If 30 circular inches be equal to one N.H.P. what is the diameter of the cylinder?

$$d^2 = \frac{a}{{\cdot}7854} = \frac{{\cdot}7854\times 30\times 90}{{\cdot}7854} = 30\times 90 = 2700$$

$$d = \sqrt{2700} = 52 \text{ inches. Answer.}$$

11. A paddle wheel is 30½ feet from centre of float to centre of float, and it makes 20 revolutions per minute, the ship makes 15 knots per hour; what is the amount and per cent of slip?

$$\frac{3{\cdot}1416\, d\, r\times 60}{6080} = \frac{3{\cdot}1416\times 30{\cdot}5\times 20\times 60}{6080}$$

$$\text{By cancelling} = \frac{3{\cdot}1416\times 30{\cdot}5\times 15}{76} =$$

knots
18·91 rate of wheel
15·00 rate of slip

3·91 slip. Answer.

knots knots knots knots
18·91 : 3·91 : 100 : 20·6 per cent. Answer.

12. A steamer runs over the measured mile in 5 minutes 10 seconds, with the tide, and in 7 minutes 30 seconds, against the tide; what was her correct rate of steaming?

m. s. m. s.
(5 10+7 30)÷2 = 380 seconds

sec. sec. mile miles.
380 : 3600 : : 1 : 9·47. Answer.

W

FIRST CLASS.

EXERCISE 4.

1. $(221-140)^{\frac{1}{2}}+7\times3 = \sqrt{81}+21 = 9+21 = 30$ Ans.

2. What is the sum of $\frac{3}{21}$ and $\frac{7}{18}$?

$$\tfrac{3}{21}+\tfrac{7}{18} = \tfrac{1}{7}+\tfrac{7}{18} = \frac{18+49}{126} = \tfrac{67}{126}.\ \text{Answer.}$$

3. $\frac{7}{19}$ of $\frac{1}{12}$ of $\frac{72}{1} = \frac{42}{19} = 2\frac{4}{19}$. Answer.

4. Some repairs took 9 men 9 hours per day for 9 days, and cost £20 3s. 9d.; if 10 men had been employed for 10 hours, how many days would they have taken? And what would have been the daily pay per man, supposing the same total sum were paid for the job?

$$\begin{array}{llll} 10 \text{ men} : & 9 \text{ men} :: & 9 \text{ days} : & 7{\cdot}29 \text{ days. Answer.} \\ 10 \text{ hours} : & 9 \text{ hours} :: & & \\ \hline 100 & 81 & & \end{array}$$

$$7{\cdot}29 \text{ days} \times 10 \text{ men} = 72{\cdot}9 \text{ days.}$$

$$\begin{array}{llll} \text{days} & \text{day} & \text{£ s. d.} & \text{s. d.} \\ 7{\cdot}29 : & 1 :: & 20\ 3\ 9 : & 5\ 6{\cdot}46. \text{ Answer.} \end{array}$$

5. A tank 60′ long, 23′ 6″ broad, and 4′ 6″ high; how long will it take to pump it out by a double-acting donkey, the diameter of whose piston is 9″, stroke 12″, revolutions per minute 70, if 15 per cent. be non-efficient?

$$\text{Time} = \frac{l\,b\,h \times 1728}{{\cdot}7854\,d^2\,s\,r \times 2 \times 60 \times f} = \frac{60 \times 23{\cdot}5 \times 4{\cdot}5 \times 1728 \times 100}{{\cdot}7854 \times 9 \times 9 \times 12 \times 70 \times 2 \times 60 \times 85}$$

$$\text{By cancelling} = \frac{23{\cdot}5 \times {\cdot}5 \times 8 \times 10}{{\cdot}7854 \times 7 \times 85} = \text{2h. 0m. } 4{\cdot}14\text{s. Answer.}$$

Note. $\dfrac{100-15}{100} = \frac{85}{100}$; $\frac{85}{100}$ inverted $= \frac{100}{85}$.

6. A condenser door is 5′ 9″ by 4′ 6″, there are 21 bolts one way and 17 the other; find the number of bolts, and the pitch, if the centres of the outside bolts be $1\frac{1}{2}$″ from the edge of the plate?

$$\begin{array}{lcc}
21 & 5'\ 9'' & 4'\ 6'' \\
21 & 3 = 1\tfrac{1}{2}\times 2 & 3 = 1\tfrac{1}{2}\times 2 \\
15 & \overline{} & \overline{} \\
15 & 5\ \ 6 & 4\ \ 3 \\
\overline{} & 12 & 12 \\
72 \text{ bolts} & \overline{} & \overline{} \\
\overline{} & 2,0)6,6 & 16)51(3\cdot1875 \text{ pitch} \\
 & \overline{} & \\
 & 3\cdot3 \text{ pitch} & \\
 & \overline{} &
\end{array}$$

See figure and remarks, page 124.

7. What is the pressure per square inch when the temperature is 80° Fahrenheit, and the barometer shews 28½" of mercury ?

Rule. $\dfrac{4907\times h}{9057+t} = \dfrac{4907\times 28\cdot5}{9057+80} = 15\cdot306$ lbs. Answer.

8. If the pressure by guage be 56 lbs., and the area of water level in the boiler be 140 square feet ; how long would it take to lower it 8", through a ⅞" rivet being blown out of the ash pit ?

Rule. $2\tfrac{1}{2}\ d^2\sqrt{P}$. Therefore; time $= \dfrac{140\times\frac{8}{12}}{2\frac{1}{2}\ d^2\sqrt{P}} = \dfrac{140\times\frac{8}{12}}{2\cdot5\times\frac{7}{8}\times\frac{7}{8}\times\sqrt{56}}$

$$= \frac{140\times8\times8\times8}{2\cdot5\times12\times7\times7\times7\cdot483} = \frac{20\times2\times8\times8}{2\cdot5\times3\times7\times7\cdot483} = 6\text{m. } 30\cdot9816\text{s.}$$

3. If it take 800 lbs. at a leverage of 12" to break a stud 1" in diameter ; what force will be necessary to break a ¾" at a leverage of 18" ?

$$18'' : 12'' :: \overset{\text{lbs.}}{800} : \overset{\text{lbs.}}{533\tfrac{1}{3}} = \overset{\text{lbs.}}{\frac{1600}{3}} = \text{force that will}$$

break a bar 1" diameter at a leverage of 18".

Now strains on bars are in proportion to the cubes of their diameters ; hence we have

$$1^3 : (\tfrac{3}{4})^3 :: \overset{\text{lbs.}}{\frac{1600}{3}} : \overset{\text{lbs.}}{x}$$

$$\therefore\ x\times1^3 = \frac{1600\times3\times3\times3}{3\times4\times4\times4} = 25\times3\times3 = 225 \text{ lbs. Ans.}$$

10. What is the weight of a cast iron ball of 8" diameter, if ·257 lbs. be equal to 1 cubic inch ?

$$\text{Weight} = d^3 \times \cdot5236 \times \cdot257$$
$$= 8^3 \times \cdot5236 \times \cdot257 = 68\cdot8973824 \text{ lbs. Answer.}$$

11. Diameter of high pressure piston is 36″, stroke 34″, and steam is carried for ½ the stroke ; there are 1300 cubic feet of steam capacity in the boilers ; how many strokes will be required to draw off that amount ?

$$\frac{\text{Cubic feet in boiler}}{\text{Cubic feet every stroke}} = \frac{1300}{\dfrac{\cdot7854\ d^2\ s}{1728 \times 2}} = \frac{1300 \times 1728 \times 2}{\cdot7854 \times 36 \times 36 \times 34}$$

$$\text{By cancelling} = \frac{1300 \times 4}{\cdot7854 \times 3 \times 17} = 129\cdot82 \text{ strokes. Answer.}$$

12. If 0·4536 kilograms be equal to 1 lb. English, and if you pay £9 10s. 4d. for 200 kilograms of tallow ; how much will that be per lb. ?

kilograms lbs.
200·0000 ÷ ·4536 = 440·92

£ s. d. d. d.
9 10 4 = 2284. 2284·00 ÷ 440·92 = 5·18. Answer.

Or thus ; kilos. kilos. £ s. d. d.
200 : ·4536 : : 9 10 4 : 5·18 Answer.

FIRST CLASS.

EXERCISE 5.

1. A ballast donkey discharges a tank in 3¼ hours alone, and the boiler donkey in 3½ hours alone; how long will they take to do it working together?

$$\text{Total time} = \frac{\text{Product of times}}{\text{Sum of times}} = \frac{3\cdot25\times3\cdot5}{3\cdot25+3\cdot5} = \text{2h. 21m. 3·816s.}$$

2. A sling chain, when lifting a 5 ton weight, forms a triangle with two sides of 7½ feet, the base is 12½ feet, and height of triangle 4·14 feet; what strain is there upon each half of the sling?

$$\text{Strain} = \frac{\text{weight}\times\text{side}}{\text{height}\times2} = \frac{5\times7\cdot5}{4\cdot14\times2} = 4\cdot529 \text{ tons. Answer.}$$

3. A packing ring of a cylinder is 73¼ inches diameter, before being cut it was 75½ inches; how much must be cut out of the circumference to make it fit the cylinder?

$$\text{Cut out} = (D-d)\times3\cdot1416 = (75\cdot5-73\cdot25)\times3\cdot1416 = 7\cdot0686 \text{ in.}$$

4. A rectangular bar is 6" deep, 3" thick, and is broken by a weight of 3200 lbs placed 35" from the point of fracture; what was the strain per square inch at the broken part?

$$S = \frac{6\,W\,L}{T\,d^2} = \frac{6\times3200\times35}{3\times6\times6} = \frac{3200\times35}{3\times6} = 6222\cdot22 \text{ lbs.}$$

5. A lead wire ·072 diameter, after testing the brasses, is flattened to ¾" broad; how many thicknesses will make one inch?

Area of rectangle = area of circle. See figure 6.

$$\text{Or breadth}\times\text{thickness} = \cdot7854\,d^2 \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad A$$

$$\therefore\ \text{thickness} = \frac{\cdot7854\,d^2}{\text{breadth}} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad B$$

$$\text{Number of thicknesses} = \frac{1}{\text{thickness}} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad C$$

$$\text{By } B.\ \text{Thickness} = \frac{\cdot7854\times\cdot072\times\cdot072\times4}{3} = \cdot2618\times\cdot072\times\cdot072\times4$$

***Note.* ¾ inverted = $\frac{4}{3}$. = ·0054286848**

By *C.* 1·000000 ÷ ·005429 = 184·2 thicknesses. Answer.

6. For steam above 12 lbs. pressure above the atmosphere, the weight of steam that will escape through an orifice one square inch in area is, in 70 seconds, just equal to the pounds of the gross pressure of steam per square inch; to what breadth of opening must a 6 inch safety valve rise to allow the escape of 10500 lbs. of steam per hour, the pressure carried being 70 lbs.?

$$\text{Breadth} = \frac{\cdot0061893 \times \text{escape of steam}}{\text{gross pressure} \times d}$$

lbs.
70 steam
15 atmos.
—
85 gross
—

$$= \frac{\cdot0061893 \times 10500}{85 \times 6} = \begin{array}{r} \cdot127 \\ 8 \\ \hline \end{array}$$

Eighths of an inch = 1·016 Answer.

7. A pair of blocks and ropes are used to hoist a weight of 1¾ tons, the rope is fastened to the top block, and there are 3 sheaves in each block; what is the strain upon the single of the rope, neglecting friction?

$$\text{Strain} = \frac{\text{Weight in lbs.}}{\text{Single parts of the rope}} = \frac{1{\cdot}75 \times 2240}{6} = 653\tfrac{1}{3} \text{ lbs.}$$

8. In the last question, supposing 10 per cent. to be lost at each sheave by friction; what will be the pull at the free end of the rope when raising the weight.

$$\frac{100-10}{100} = \frac{90}{100} = \frac{9}{10} = 9.$$ Find the sum of the power of ·9 to the sixth

$$\cdot9 + \cdot81 + \cdot729 + \cdot6561 + \cdot59049 + \cdot531441 = 4{\cdot}217031$$

$$\frac{2240 \times 1{\cdot}75}{4{\cdot}217031} = 929.56 \text{ lbs. Answer.}$$

9. If the compression of a spring that loads a safety valve be 2 inches, and the pressure to which the valve is loaded 65 lbs. per square inch: what will be the load per square inch on the valve when it is lifted to give an area of escape equal to ¼ of the area of the valve. The face of the valve is flat. The valve is 6 inches diameter?

$$\text{Extra weight} = \frac{d \times 1 \times \text{lbs. per square inch}}{4 \times 4 \times \text{compression}} = \frac{6 \times 1 \times 65}{4 \times 4 \times 2}$$

$$= 12{\cdot}1875 \text{ lbs.}$$

$$65 + 12{\cdot}1875 = 77{\cdot}1875. \text{ Answer.}$$

10. The connecting rod is adjusted by a screwed cutter, the screw has 13 threads to the inch, the taper of the cutter is ⅜" to the foot, the nut is 6 canted ; required the number of turns and cants of the nut to bring the brasses ·01 closer ?

$$\begin{array}{lll} \text{Taper } 3{\cdot}0 \div 8 & = & {\cdot}375 \text{ of an inch to a foot} \\ {\cdot}375 \div 12 & = & {\cdot}03125 \text{ of an inch to an inch} \\ {\cdot}03125 \div 13 & = & {\cdot}002404 \\ {\cdot}010000 \div {\cdot}002404 & = & \left.\begin{array}{l} 4{\cdot}1597 \text{ complete turns} \\ \quad\quad\ \ 6 \\ \hline {\cdot}9582 \text{ cants} \\ \hline \end{array}\right\} \text{ Answers.} \end{array}$$

11. If 29 circular inches be equal to 1 N.H.P., what is the mean effective pressure per square inch required to indicate 3·8 times the N.H.P., if the piston run 400 feet per minute ?

$$\frac{33000 \times 3{\cdot}8}{{\cdot}7854 \times 29 \times 400} = \frac{330 \times 3{\cdot}8}{{\cdot}7854 \times 29 \times 4} = 13{\cdot}76 \text{ lbs. Answer.}$$

12. When a safety valve has the area required by the Board of Trade, and is spring loaded, the increase of pressure due to the increased compression of the spring in blowing off steam is, with bright fires and engines stopped, about equal to the quotient found by dividing the diameter of the valve by its original compression.

Question.—The spring has 6" compression, there are 50 square feet of fire grate to one valve, the loaded pressure is 50 lbs., the increase, irrespective of the spring, would be, say 10 per cent. ; to what pressure would the steam rise, including the effect of the spring ?

$$\begin{array}{l} 2)\underline{50} \text{ sq. ft. fire grate.} \\ \ \ \ 25 \text{ sq. in. valve.} \end{array} \qquad d^2 = \frac{a}{{\cdot}7854} = \frac{25}{{\cdot}7854} = 31{\cdot}83$$

$$d = \sqrt{(31{\cdot}83)} = 5{\cdot}6418. \qquad \begin{array}{rr} & \text{compress } d. \\ & 6)\underline{5{\cdot}6418} \\ \text{increase} & \underline{{\cdot}9403} \end{array}$$

	lbs.
Original pressure	50
10 per cent.	5
Increase	·9403
Steam rises to	55·9403 Answer.

FIRST CLASS.

EXERCISE 6.

1. $24-\sqrt{(16)}-(9+11)^2 = 24-4-400 = 24-404 = -380$

2. If 1 ton stretch a bar of iron 1 in 19000; what will 8 tons stretch a bar 20 feet long ?

$$\begin{array}{llr} 20 \text{ feet} & 19000'' : 240'' :: 1'' : & \cdot0126'' \\ \underline{12} & & \underline{8 \text{ tons}} \\ \underline{240 \text{ inches}} & & \underline{\cdot1008} \text{ Answer.} \end{array}$$

3. An engine was compounded, and the same expenditure of fuel shewed 20 per cent. more power than on the old principle ; it works to the same H.P., it used 12 tons of coals per day formerly, how many tons will it use now ?

$$120 : 100 :: \overset{\text{tons}}{12} : \overset{\text{tons}}{10.} \text{ Answer.}$$

4. According to B.T. instructions. Circular furnaces with the longitudinal joints welded, or made with a butt strap.

$$\frac{90000\times(\text{thickness of plate, in inches})^2}{(\text{Length, in feet}+1)\times\text{diameter, in inches}} = \text{working press. per sq. in. } A$$

Without the Board's special approval of the plans, the pressure is in no case to exceed

$$\frac{8000\times\text{thickness, in inches}}{\text{Diameter, in inches}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad B$$

Find the working pressure when the diameter is 36″, length of tube 6′ 4″, and thickness of plate $\frac{3}{8}''$?

$$\text{By } A. \quad \frac{90000\times3\times3}{7\cdot3333\times36\times8\times8} = \frac{2500\times3\times3}{7\cdot333\times8\times8} = 47\cdot94 \text{ lbs. Ans.}$$

$$\text{By } B. \quad \frac{8000\times3}{36\times8} = \frac{1000}{12} = 83\cdot33 \text{ lbs. Answer.}$$

5. For arithmetical convenience, reckoning the total heat in steam of T° temperature to be equal to $1115^\circ+\cdot3T^\circ$, the difference between this amount and t°, the temperature of feed, is the number of units of heat to each lb. of water evaporated; how many units of heat, and what latent heat, are there in steam of a temperature of 300° ?

$$1115+\cdot3\times300-300 = 1115+90-300 = 905. \text{ Ans.}$$

6. If a certain quantity of fuel evaporate 8 times its weight of water from and at 212°, how much will 1 lb. of fuel evaporate if the steam be 300° and the feed water 110° ?

$$1115+\cdot3\times212 \;=\; 1115+63\cdot6 - 212 \;=\; 966\cdot6$$
$$1115+\cdot3\times110 \;=\; 1115+33 - 110 \;=\; 1038$$

1038 : 966·6 : : 8 : 7·45. Answer.

7. The consumption of coals per day is 28 tons, and each watch of 4 hours throws overboard 36 baskets of ashes, each weighing 48 lbs. ; what per centage of coal is lost as ashes ?

$$\frac{48\times36\times6}{2240} = 4\cdot6 \qquad 28 : 4\cdot6 :: 100 :: 16\cdot4.\ \text{Ans.}$$

8. The actual H.P. transmitted in the tunnel shaft is 400, revolutions per minute are 60, there are 5 bolts at each coupling of 2½″ diameter, and 12½″ radius ; what is the mean shearing strain per square inch on the bolts ?

$$33000\times400 = \text{foot lbs.} = \text{lbs. weight}\times\text{feet moved per minute}$$

$$\therefore \text{lbs. weight} = \frac{33000\times400}{\text{feet moved per minute}} = \frac{33000\times400\times12}{3\cdot1416\times25\times60} \ldots A$$

$$= \frac{400\times12}{\cdot1428} = 33613\cdot45 \text{ lbs. on all the bolts}$$

$$\therefore \frac{33613\cdot45}{5} = 6722\cdot69 \text{ lbs. on every bolt.}$$

$$\therefore \frac{6722\cdot69}{\cdot7854\times2\cdot5\times2\cdot5} = 1369\cdot5 \text{ lbs. per square inch. Answer.}$$

Note. In equation *A*. $\dfrac{\text{Numerator}}{\dfrac{\text{Denominator}}{12}} = \dfrac{\text{Numerator}\times12}{\text{Denominator}}$

9. A portion of air is heated to 39°, and it is 14·7 lbs. pressure ; if it be afterwards heated to 79°, what is then its pressure ?

Note.—Absolute zero is 461° below zero of Fahrenheit.

$$\begin{array}{rrl} 461^\circ & 461^\circ & 540^\circ : 500^\circ :: \overset{\text{lbs.}}{14\cdot7} : \overset{\text{lbs.}}{13\cdot61}.\ \text{Ans.} \\ 39 & 79 & \\ \hline 540 & 540 & \\ \hline \end{array}$$

10. An engine is contracted for to have 28 circular inches of cylinder per N.H.P., and it is to indicate 4 times the N.H.P., to have 42" stroke, and 20 lbs. mean effective pressure ; how many revolutions must it make to fulfil the contract ?

$$\frac{33000\times4}{\cdot7854\times28\times20\times7} = \frac{150}{\cdot0714\times7\times7} = 42\cdot9 \text{ revolutions. Ans.}$$

Note.—Stroke × 2 = 42" × 2 = 84" = 7'.

11. Find the thermal units of heat in an engine of the following dimensions ; diameter of cylinder 70", stroke 36", revolutions 60 per minute, and pressure per square inch 38 lbs. ; also find the coal burnt per hour ?

Note.—1 lb. good coal gives 8000 thermal units of heat, but by the time it gets to the piston it is only equal to 800 units.

$$\frac{70\times70\times\cdot7854\times38\times6\times60}{772\times800} = \frac{70\times7\times\cdot7854\times38\times6\times6}{772\times8} \text{ thermal units} = 85\cdot2444$$

$$\frac{85\cdot2444\times60}{2240} = 2\cdot283 \text{ tons. Answer.}$$

12. The surface of a screw propeller being oblique to the direction of the thrust, the area of screw disc is less effective for thrust than an equal area of feathering float immersion with the same slip, according to the following *formula.*

$$A = \left\{\cdot7854 - \frac{P}{5D}\right\}(D^2 - B^2)$$

Where A = effective area of screw disc ; in square feet
P = pitch
D = diameter of propeller } in lineal feet.
B = diameter of boss.

Question.—The diameter of the screw propeller is 16 feet, that of the boss is 3·2 feet, and the pitch is 28 feet ; what is the equivalent perpendicular area of feathering paddle floats ?

By substitution in the formula we have

$$\left\{(\cdot7854 - \frac{28}{5\times16}\right\}(16^2 - 3\cdot2^2) = \cdot4354\times245\cdot76 = 107\cdot0039 \text{ sq. ft.}$$

13. What is the thrust in lbs. when the ship is making 14 knots per hour, with 64 revolutions per minute ?

Formula. $T = 5{\cdot}67\,K\,k \times \text{equivalent area}$

Where T = thrust in lbs.

K = knots per hour

k = slip, in knots per hour

Equivalent area = 107 ; from preceding question

$$k = \frac{14 \times 64 \times 2 \times 60}{6080} - 14 = \frac{7 \times 8 \times 6}{19} - 14 = 3{\cdot}68 \text{ slip}$$

$$T = 5{\cdot}67 \times 14 \times 3{\cdot}68 \times 107 = 31256{\cdot}6688 \text{ lb. Answer.}$$

14. According to the above statement, what is the loss of work by slip in actual H.P.

$$\frac{6080 \times 3{\cdot}68}{60} = 372{\cdot}906$$

$$\frac{31256{\cdot}669 \times 372{\cdot}906}{33000} = 353{\cdot}206. \text{ Answer.}$$

15. Practically we find that 38½ per cent. of the I.H.P. is lost by the slip ; what was the I.H.P. of the above engines ?

	per cent.		per cent.		I.H.P.		I.H.P.	
As	38·5	:	100	: :	353·2	:	917·4.	Answer.

FIRST CLASS.

EXERCISE 7.

1. A circular safety valve weight is 84 lbs., and a cubic inch weighs ·257 of a lb.; what is the diameter of the weight when the thickness is 1¾".

From the fundamental formula $\cdot 7854\, d^2 t \times \cdot 257 = w$, we have

$$d = \sqrt{\left(\frac{w}{\cdot 7854\, t \times \cdot 257}\right)} = \sqrt{\left(\frac{84}{\cdot 7854 \times 1\cdot 75 \times \cdot 257}\right)}$$

$$= \sqrt{(287\cdot 80)} = 15\cdot 42 \text{ inches. Answer.}$$

2. Suppose there be 16 of those weights on a valve 5" diameter; what is the pressure per square inch? And if the bottom of the weights be 2" above the valve; what extra weight will there be if the bore be full of water to the top of the weights?

$$\frac{\text{Total weight}}{\text{Area of valve}} = \frac{84 \times 16}{\cdot 7854 \times 5^2} = 68\cdot 45 \text{ lbs. Ans. to the first question.}$$

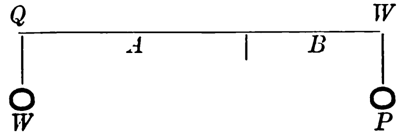
The water in the bore will be a cylinder, of which the part from the top of the weights to the bottom of them will be hollow, and assuming that the diameter of the weights may be made *as near as we please* to that of the bore, the sides of this hollow cylinder may become *as thin as we please*, and its volume may become *as small as we please*; hence we need only consider the solid cylinder of water 2" deep below the weights, and by the formula

$h \div 2\cdot 305 =$ weight in lbs; we have $\frac{2}{12}' \div 2\cdot 305 = \cdot 166\dot{6} \div 2\cdot 305$
$= \cdot 072$ lbs. per sq. inch extra weight. Ans. to the second question.

3. If 9200 lbs. be expended on a thrust, the mean radius of the rubbing surface of which is 5", the co-efficient of friction being ·09, and the engines making 48 revolutions per minute; what is the loss with the friction on I.H.P.?

$$\frac{9200 \times \cdot 09 \times 3\cdot 1416 \times 10 \times 48}{12 \times 33000} = 92 \times \cdot 03 \times \cdot 2856 \times 4 = 3\cdot 153024 \text{ HP.}$$

4. A beam as in the annexed sketch is balanced as follows:—



$$\left.\begin{array}{lcl} \text{Let } A & = & \text{long arm} \\ B & = & \text{short arm} \\ W & = & \text{correct weight} \\ P & = & \text{weight when } W \text{ is at the end of } A \\ Q & = & \text{weight when } W \text{ is at the end of } B \end{array}\right\} \text{ in lbs.}$$

Then by the principle of the lever

$$W \times A = P \times B \quad \therefore \quad W^2 \times AB = PQ \times AB$$

$$W \times B = Q \times A \quad \therefore \quad W = \sqrt{(PQ)} \quad \dots\dots\dots\dots\dots\dots \quad a$$

Question. The weight $P = 296$ lbs. and $Q = 336$ lbs.; what is the correct weight ?

By substitution in equation *a*. Weight $= \sqrt{(296 \times 336)} = 315{\cdot}37$ lbs.

5. If a boiler use 1800 lbs. of coal per hour, and each lb. of coal evaporate 8 lbs. of water, using fresh water, what is the smallest diameter in inches of the nozzle of an injector to put in the double feed at 60 lbs. pressure by the guage ?

Rule. $\left\{\begin{array}{l}\text{Smallest area in square inches} \\ \text{Smallest area in circular inches}\end{array}\right\} = \dfrac{\text{Cubic feet per hour of feed}}{630\sqrt{P}}$

$$\sqrt{P} = \sqrt{(60+15)} = 8{\cdot}66. \quad \sqrt{\left(\frac{1800 \times 8 \times 2}{62{\cdot}5 \times 630 \times 8{\cdot}66}\right)}$$

$$= \sqrt{\left(\frac{20 \times 8 \times 2}{62{\cdot}5 \times 7 \times 8{\cdot}56}\right)} = \sqrt{({\cdot}0844)} = {\cdot}29. \quad \text{Ans.}$$

6. If the counter advance from 081376 to 418397 in 84 hours ; what will it stand at after 360 hours ?

$$\begin{array}{r} 418397 \\ 081376 \\ \hline 337021 \\ \hline \end{array} \qquad 84 : 360 :: 337021 : 1444375$$

$$\begin{array}{r} 1444375 \\ +081376 \\ \hline 1525751 \\ -\ 1000000 \\ \hline 525751 \text{ Ans.} \\ \hline \end{array}$$

7. If a continual blow off at ·125 of the feed, and if the boiler water retain 11 oz. of salt to the gallon ; what saltness has the feed water been at ?

${\cdot}125 = \dfrac{125}{1000} = \frac{1}{8}$. Hence in 8 gallons of feed 1 gallon is blown off.

Let x = oz. of salt in 1 gallon of feed ; then $x \times 8 = 1 \times 11$

$\therefore\ x = \frac{11}{8} = 1\frac{3}{8}$ oz. Answer.

8. A shaft 12″ diameter is put to torsional strain by a weight of 500 lbs. acting with a leverage of 68″, find the maximum stress per square inch of section ?

$$\frac{5{\cdot}1 \times 500 \times 68}{12^3} = 100{\cdot}347 \text{ lbs. Answer.}$$

9. How far can the visible horizon be seen, when the eye is 26 feet above the sea ?

Rule. Miles = $\sqrt{(\text{height} \times 1{\cdot}5)} = \sqrt{(26 \times 1{\cdot}5)} = \sqrt{(39)} = 6{\cdot}24$

10. The temperature of gases in the combustion chamber was 1200° *F*, and at the front plate 600° *F* ; the velocity at the back was 1200 feet per minute, what was the velocity at the front ?

Rule. Absolute zero is 461° below zero of Fahrenheit.

1200°	600°		
461	461	1661° : 1061° : :	ft. 1200 : ft. 766·5. Ans.
1661	1061		

$$\text{11. } 88 - \frac{220 \times t}{np + 3t} = \text{per centage of strength of longitudinal seams}$$

of a boiler ; where t = thickness of plates, p = pitch of rivets, and n = number of rows of rivets.

Question.—The thickness of plate is 1″, the pitch 2″, the number of rows of rivets 2, single shear ; what is the per centage of strength, the diameter of the rivets not being known ?

$$\frac{220 \times t}{np + 3t} = \frac{220 \times 1}{2 \times 2 + 3 \times 1} = \frac{220}{4+3} = \frac{220}{7} = 31\tfrac{3}{7}. \qquad \begin{array}{r} 88 \\ -\,31\tfrac{3}{7} \\ \hline 56\tfrac{4}{7} \end{array} \text{ Answer.}$$

Note.—According to the density of steam at 18 lbs. gross pressure, that is about 3 lbs. above the atmosphere by the steam guage, it would take just 35 lbs. weight per hour to produce one I.H.P. if worked without expansion, and also without back pressure or other loss. At high pressures less than 35 lbs. of steam would produce the same result ; but there are several considerations which lead to the adoption of 35 lbs. as a convenient standard in estimating approximately the cost of evaporation, and of H.P. from indicator diagrams.

Divide the length of the card into ten equal parts ; measure from perfect vacuum line, the pressure shown on the cards at 8÷10 of the stroke from the beginning at both ends, add these together, multiply the sum by the square of the diameter of the cylinder, in inches, by the length of the stroke, in feet, and by the revolutions per minute ; divide the product by 140000, the quotient will be the tons of steam used as shewn by the card for 24 hours working.

$$\text{Or } \frac{(P_1+P_2)\,d^2\,l\,r}{140000} = \text{tons of steam for 24 hours}$$

The above is exclusive of steam condensed in the cylinder, and of the effect of clearance ; the rule is stated for one cylinder.

12. Given the diameter of cylinder 5′ 6″, length of stroke 3′ 6″, revolutions per minute 60, and from the card No. 1, Plate 8 $P_1 = 22{\cdot}2$ $P_2 = 23{\cdot}2$; required the tons of steam for 24 hours. See page 183.

$$\frac{(P_1+P_2)\,d^2\,l\,r}{140000} = \frac{45{\cdot}4\times66\times66\times3{\cdot}5\times60}{140000} = \frac{45{\cdot}4\times33\times66\times{\cdot}5\times6}{1000}$$

$$\begin{aligned} P_1 &= 22{\cdot}2 \\ P_2 &= 23{\cdot}2 \\ P_1+P_2 &= 45{\cdot}4 \end{aligned} \qquad = 296{\cdot}6436 \text{ tons of steam in 24 hours. Ans.}$$

13. What is the atmospheric pressure in lbs. per square inch in the diagram ; the weather barometer shewing 29 inches, if 2·04 inches mercury were equal to 1 lb. per square inch ?

$29\div2{\cdot}04 = 14{\cdot}216$ lbs. of atmospheric pressure, or perfect vacuum.

14. Draw the line of perfect vacuum on the diagram, and measure off the pressure denoted by P_1 and P_2 in the above rule ; viz., the gross pressure at 8÷10 of the stroke ; P_1 being the down stroke, and P_2 the up stroke.

$$P_1 = 22{\cdot}2 \text{ lbs.} \quad P_2 = 23{\cdot}2 \text{ lbs.}$$

15. What is the I.H.P. of the engine whose diameter of cylinder, length of stroke, and revolutions per minute are given in question 12 ?

By the diagram the mean effective pressure is 29·6 lbs. per square inch ; hence

$$\text{H.P.} = \frac{{\cdot}7854\,d^2\,p\,s\times2\,r}{33000} = \frac{{\cdot}7854\times66\times66\times29{\cdot}6\times7\times60}{33000}$$

$$= \frac{{\cdot}7854\times2\times66\times29{\cdot}6\times7\times6}{100} = 1288{\cdot}86. \text{ Answer.}$$

16. And what is the least consumption per I.H.P. per hour which would give 10 lbs. of evaporation for 1 lb. of coal ?

$$\text{Least consumption} = \frac{\text{tons steam}\times2240}{\text{lbs. evap.}\times24\times\text{H.P.}} = \frac{296{\cdot}6436\times2240}{10\times24\times1288{\cdot}86}$$

$$= 2{\cdot}148 \text{ lbs. per I.H.P. per hour. Answer.}$$

MISCELLANEOUS QUESTIONS.

See Question 8, page 111. The exact *formulæ* for questions relating to all kinds of regular figures; such as frustums of cones, pyramids, and so on; are

$$\text{Volume} = (A + a + \sqrt{A\,a})\frac{h}{3} \quad \ldots\ldots\ldots\ldots\ldots \quad 1$$

$$\text{Or Volume} = (A + a + 4\,M)\,\frac{h}{6} \quad \ldots\ldots\ldots\ldots\ldots \quad 2$$

Where A = area of large end
a = area of small end
M = area of middle section
h = height

Example.—Required the volume of a waggon-shaped bunker, 3 feet by 4 at the bottom, 6 feet by 8 at the top, and 18 feet deep?

By *Formula* 1.

$$\text{Volume} = \left\{(6\times8)+(3\times4)+\sqrt{(6\times8)\,(3\times4)}\right\}\frac{18}{3} = \overset{\text{Answer.}}{504 \text{ cubic ft.}}$$

By *Formula* 2.

$$\text{Volume} = \left\{(6\times8)+(3\times4)+4\,\left(\frac{6+3}{2}\right)\left(\frac{8\times4}{2}\right)\right\}\frac{18}{6} = \overset{\text{Answer.}}{504 \text{ cubic ft.}}$$

A ship will always steam further with a given quantity of fuel by using only part of her power, then by going full speed, provided no steam is wasted, and that the part of power used is sufficient to give headway equal to 1½ times the opposing force. Thus, in a tide, or current, running 4 knots against the ship, for the greatest economy of the fuel, she should steam 6 knots through the water.

The following statement has been amply verified by numerous experiments.

THE POWER VARIES AS THE CUBE OF THE SPEED.

Hence we have the following proportion:—

$$P : p :: S^3 : s^3 \quad \ldots\ldots\ldots\ldots\ldots \quad A$$

Where P = greater power
p = lesser power
S = greater speed
s = lesser speed

Example 1. A vessel goes at full speed 10 knots per hour when consuming 9 tons of coals per day; what will her speed be when she is only consuming 5 tons per day?

From A we have

$$s^3 = \frac{p\,S^3}{P} \quad \therefore \quad s = \frac{(5 \times 10^3)^{\frac{1}{3}}}{9}$$

And solving this expression by logarithms we have:

$$\log.\ s = \frac{\log.\ 10 \times 3 + \log\ 5 - \log.\ 9}{3}$$

10 log. 1·000000
3
3·000000
5 log. 0·698970
3·698970
9 log. 0.954243
3)2·744727
8·221 log. 0·914909

Answer 8·221 knots per hour.

Example 2. A vessel steams 10 knots per hour, and burns 9 tons of coals per day, suppose her speed be reduced to 8·221 knots per hour, what will her consumption be per day?

From A, we have:

$$p = \frac{P\,s^3}{S^3} = \frac{9 \times 8{\cdot}221^3}{10^3}$$

Hence, by logarithms, we have:

$$\log.\ p = \log.\ 9 + \log.\ 8{\cdot}221 \times 3 - \log.\ 10 \times 3$$

8·221 log. 0·914925
3
2·744775
9· log. 0·954243
3·699018
3·000000
5· log. 0·699018

10 log. 1·000000
3
3·000000

Answer 5 tons per day.

Questions founded on the following formulæ are sometimes given by the Examiners.

$$K^2 m = k^2 M \ldots\ldots A$$

Where K = original knots per hour the ship steamed.
k = knots per hour the ship will now steam.
m = original miles the ship had to go.
M = miles the ship has now to go.

Example **1. A vessel is coaled for a voyage of 1200 miles, and she will steam 10 knots per hour, orders are received at the last moment to proceed to another port 1800 miles distant; what must her speed be to make the coal serve the voyage?**

From equation A, we have.

$$k = \sqrt{\left\{\frac{K^2 m}{M}\right\}} = \sqrt{\left\{\frac{10^2 \times 1200}{1800}\right\}} = 8{\cdot}16496 \text{ knots per hour. Answer.}$$

Example **2. A vessel uses all the coals her bunkers can contain to go 1200 miles at 10 knots per hour, her speed is reduced to 8·16496 knots per hour; how far will the same quantity of coals carry her?**

$$M = \frac{K^2 m}{k^2} = \frac{10^2 \times 1200}{(8{\cdot}16496)^2} = 1800{\cdot}0002 \text{ miles Answer.}$$

1. No. 5 line is the area of a square, and No. 2 line is the area of a circle; find the diameter of a circle equal to the sum of these?

No. 1 line	6·7567
No. 2 ,,	·634
No. 3 ,,	4·0
No. 4 ,,	·0697
No. 5 ,,	1·764
No. 6 ,,	·10108
No. 7 ,,	0·7654

Note. The applicant may think it is wrongly worded, or put, but he is cautioned to take the question as it reads.

$$\text{Diameter} = \sqrt{\left\{\frac{{\cdot}634 + 1{\cdot}764}{{\cdot}7854}\right\}} = 1{\cdot}747 \text{ Answer.}$$

2. Find the N.H.P. of the engines you were with last, and find the maximum strain on the crank pin? Give the name of the steamer for verification.

Example. Cylinders 32" and 63", steam 60 lbs., crank pin 12" diameter × 12" long.

$$\text{N.H.P.} = \frac{32^2 + 63^2}{32} = 156{\cdot}03$$

$$\text{Pressure per square inch} = \frac{{\cdot}7854 \times 32 \times 32 \times 60}{12 \times 12} = 335{\cdot}104 \text{ lbs.}$$

3. A counter at starting stood at 918376, and has been round once and stops at 043721, the ship has been steaming from the 16th January at noon to the 22nd at 5 A.M.; what has been the mean number of revolutions per minute?

5 days 17 hours = 8220 minutes.

$$\frac{(1000000 - 918376) + 1000000 + 43721}{8220} = 136{\cdot}9 \text{ Answer.}$$

4. 1256·64 square inches are added to $1814\frac{1}{16}$ circular inches; find the diameter of a circle which would have the same area as their sum?

$$1814{\cdot}0625 \times {\cdot}7854 = 1032{\cdot}0646875$$

$$\sqrt{\left\{\frac{1256{\cdot}64 + 1032{\cdot}0646875}{{\cdot}7854}\right\}} = 53{\cdot}98 \text{ Answer.}$$

5. The area of water level in the boiler is 2·1 times the area of the fire grate, there is consumed 13 lbs. of coals on each square foot of fire grate per hour, each lb. of coal evaporates 8 lbs. of water, the feed is shut off when there are 4" of water in the glass; in how many minutes will the water be out of sight?

$$\begin{array}{rl} 13 & \text{lbs. coals} \\ 8 & \text{lbs. water} \\ \hline 104 & \text{lbs. water} \end{array} \qquad 4'' = \frac{4'}{12} = \frac{1'}{3} \qquad \begin{array}{r} 2{\cdot}1 \\ 1 \\ \hline 3)2{\cdot}1 \\ \hline {\cdot}7 \\ 62{\cdot}5 \\ \hline 43{\cdot}75 \\ \hline \end{array}$$

$$\begin{array}{ccccccccc} \text{lbs.} & & \text{lbs.} & & \text{min.} & & \text{min.} & \text{sec.} & \\ 104 & : & 43{\cdot}75 & :: & 60 & : & 25 & 14{\cdot}4 & \text{Answer.} \end{array}$$

6. The I.H.P. was 500, the thrust block takes 32 per cent. of it, revolutions per minute 80, pitch 20 feet, and the slip 20 per cent.; what weight is against the thrust block ?

$$\begin{array}{lllllll} 100 & : & 32 & :: & 500 & : & 160 \qquad 100-20 = 80 \\ 100 & : & 80 & :: & 20 & : & 16 \qquad 16\times 80 = 1280 \end{array}$$

$$\frac{160\times 33000}{1280} = \frac{33000}{8} = 4125 \text{ lbs. Answer.}$$

7. A ship's draft of water before taking in her bunker coals was 17 feet forward and 18½ feet aft, and it was found that every 16 tons put her down one inch; after taking in her bunker coals she drew 18½ feet forward and 19¾ feet aft; how many tons were put into the bunkers, and what was the area of the section of the ship at the water line in square feet ?

$(17+18{\cdot}5)\div 2 = 17{\cdot}75$; $(18{\cdot}5+19{\cdot}75)\div 2 = 19{\cdot}125$

$(19{\cdot}125-17{\cdot}75) = 1{\cdot}375$

$1{\cdot}375\times 12\times 16 =$ 264 tons First Answer.

$$\text{Area} = \frac{264\times 35}{1{\cdot}375} = \frac{264\times 7}{{\cdot}275} = 6720 \text{ square feet. Second Answer}$$

8. The stroke of the piston is 46″, the length of the connecting-rod is 8ft., the steam was cut off at 22″ from the bottom ; required the distance from the centre of the cross head to the centre of the shaft ? And the lap and lead being the same top and bottom, where does she cut off from the top ?

$$\begin{array}{rl} 2)46 & \\ \hline 23 & \text{half stroke} \\ 22 & \text{cut off} \\ \hline 1 & \text{down} \end{array} \qquad \begin{array}{rl} 8' & 0'' \\ & 1 \\ \hline 7 & 11 \quad \text{from centre} \\ 12 & \\ \hline 95 & \end{array}$$

$$\begin{array}{rl} 46 & \\ 22 & \\ \hline 24 & \text{from up} \end{array} \qquad \frac{22\times 24}{95} = 5{\cdot}55 \qquad \begin{array}{r} 22 \\ 5{\cdot}55 \\ \hline 27{\cdot}55 \end{array} \text{ Answer.}$$

9. The diameter of the L.P. cylinder is 58 inches, and the area of the two cylinders are to each other as 1 is to 3·5, the effective pressure per sq. inch at the beginning of the stroke is 20lbs. on the L.P. piston, and 70lbs. on the high pressure piston, the diameter of crank pin is 10″, and its length 10″; what is the pressure per sq. inch on the surface of the crank pins, supposing the brasses to be a perfect fit ?

$$\text{Area of L.P.} = \cdot 7854 \times 58^2 = 2642\cdot 0856$$

$$\text{Area of high pressure} = \frac{.7854 \times 58^2}{3\cdot 5} = 754\cdot 8816$$

$$\text{Pressure of L.P. crank pin} = \frac{2642\cdot 0856 \times 20}{10 \times 10} = 528\cdot 4171\text{lbs.}$$

$$\text{Pressure on H.P. crank pin} = \frac{754\cdot 8816 \times 70}{10 \times 10} = 528\cdot 4171\text{lbs.}$$

A hole of 1 square inch area, if 20ft. below the water level, admits 20 tons of water in one hour, and the law for any other depth varies as the square root of the depth.

Let d = depth in feet.
Let q = quantity in tons.

$$\text{Then } \sqrt{\left\{\frac{d.}{20}\right\}} = \frac{q.}{20} \text{ and by squaring.}$$

$$\frac{d.}{20} = \frac{q^2.}{20^2}$$

$$\therefore d. = \frac{20q^2}{20 \times 20} = \frac{q^2}{20}$$

$$20d. = q^2$$

$$\therefore q. = \sqrt{(20d.)}$$

Example 1. A hole of 5 inches area admits 240 tons of water in one hour, how much is that hole below the water level?

5)240

48 tons that one inch admits.

$$\text{then } d. = \frac{48^2}{20} = 115\cdot 2 \text{ feet.—Ans.}$$

Example 2. A hole having 5 inches area is 25 feet below water level, what quantity of water will it admit?

$$q = \sqrt{20d} = \sqrt{(20 \times 25)}$$

$$= \sqrt{500} = 22\cdot 36 \text{ tons for 1 inch.}$$

5 inches

Ans. 111·80 tons.

ON THE TEMPERATURE OF MIXED WATER AND ICE.

Formula

$$\frac{\text{Temperature of water} \times \text{lbs. of water} + \text{temp. of ice} + \text{lbs. of ice} —}{\text{lbs. of water} + \text{lbs. of ice}}$$

$$\frac{\text{latent heat of water} \times \text{lbs. of ice}}{\text{lbs. of water} + \text{lbs. of ice.}} = \text{resulting temperature}$$

If 9 lbs. of ice be mixed with 10 lbs. water at 100° C; what is the result? See "Evers on the Steam Engine," page 338.

The freezing point of water is at 0° in the Centigrade scale, and the latent heat of water is at 79·4° in the same scale; hence, by the formula we have

$$\frac{100 \times 10 + 0 \times 9 — 79{\cdot}4 \times 9}{10 + 9} = 15{\cdot}02$$

Therefore the result is 19 lbs. of water at 15·02° C.

Again; what is the result in the above question by Fahrenheit's scale?

The equivalent of 0° C. is 32° F., and that of 100° C is 212° F., also the latent heat of water is about 143° F.; hence, by the formula we have

$$\frac{212 \times 10 + 32 \times 9 — 143 \times 9}{10 + 9} = 59$$

Therefore the result is 19 lbs. of water at 59° F.

Now, from the former result we have $F = \frac{C \times 9}{5} + 32$

$= \frac{15{\cdot}02 \times 9}{5} + 32 = 59$ nearly, which agrees nearly with the latter result.

If the heat to melt 1 lb. of ice be sufficient to raise 144 lbs. water one degree. Then if 42 lbs. of ice be mixed with 120 lbs. of water at 212° F.; what will be the resulting temperature?

$$\frac{212 \times 120 - 42\,(144 - 32)}{120 + 42} = 128^\circ\text{F. Answer.}$$

Note. This solution is derived from the preceding formula.

1. If the salt brought in by the feed water be ·01 oz. to the gallon, and the boiler water be at 12 oz. to the gallon; what proportion of feed should be blown off?

$$\frac{\cdot0100}{\cdot12} = \cdot083 \text{ Answer.}$$

2. 4 furnaces 6′ 2″ by 3′ 2″ take 16 lbs. of coal per hour per square foot grate surface, and every lb. of coal evaporate 9 lbs. of water, the boiler contains 3·5 cubic feet for every square foot of grate; how many tons of coals will be used in 6 hours' steaming? And what is the amount of evaporation?

$$\frac{74 \times 38 \times 4}{12 \times 12} = 78\cdot1111 \text{ square feet fire grate.}$$

Note. $6'\,2'' = \frac{74}{12}$; $3'\,2'' = \frac{38}{12}$

$$\frac{78\cdot1111 \times 16 \times 6}{2240} = \frac{7498\cdot6667}{2240} = \begin{array}{rl} & \text{tons.} \\ 3\cdot347 & \text{coals used in 6 hours} \\ 9 & \\ \hline 30\cdot123 & \text{water evaporated in 6 hours.} \end{array}$$

3. What is now the density of water in the boiler, the feed being the same, and the boiler filled up with sea water?

$78\cdot1111 \times 3\cdot5 = 273\cdot38889$ cubic feet $= a$

$7498\cdot6667 \times 9 \div 62\cdot5 = 1079\cdot81$ tons water $= b$

$$\begin{array}{ccccccc} a & & b & & \text{oz.} & & \text{oz.} \\ 273\cdot4 & : & 1079\cdot8 & :: & 5 & : & 19\cdot75 \text{ Answer.} \end{array}$$

4. What horse power will the boiler work up to, if it give out 19 lbs. of steam per I.H.P. per hour?

$7498\cdot6667 \times 9 \div 19 \times 6 = 592$ I.H.P.

5. State how many tubes you would allow for the furnaces, give their length and diameter, and what area that would give per square foot of fire grate?

Say 55 tubes to a furnace, or 220 in the boiler, length 6 feet, diameter 3 inches.

$$\frac{\text{Area of tubes in square feet}}{\text{Area of fire grate in square feet}} = \frac{3{\cdot}1416 \times {\cdot}25 \times 6 \times 220}{78{\cdot}11} = 13{\cdot}27$$

Answer 13·27 square feet of tubes to a square foot of fire grate.

PART THIRD.

INTRODUCTION.

Matter is that which fills space.

Bodies are limited portions of matter. Bodies exist in three distinct conditions, the Solid, the Liquid, and the Gaseous. Solid bodies tend to preserve a definite size and shape. Liquid bodies tend to preserve a definite size only. Gaseous bodies tend to expand indefinitely. The same body may exist in any of these three conditions ; thus ice may melt and become water, and the particles of water may separate and take the gaseous form.

The **Atmosphere** is that great ocean of air in which we live, move, and have our being.

WEIGHT OF AIR.

The Barometer.—The Grand Duke of Tuscany put pumps in his fountains which were required to draw water from a depth of from 40 to 50 feet; when those pumps were worked it was found that they would not draw the water ; the great philosopher Galileo was consulted on the subject and he observed that the water only rose to a height of 32 feet in the pumps, and he conceived the idea that it was the weight of a column of the atmosphere which maintained the water at that height.

Torricelli, his celebrated pupil, made the following experiment ; he took a tube, closed at one end and open at the other, of about a quarter, or a third of an inch, in diameter, and about three feet long, and completely filled it with mercury, he then stopped the open end with his finger and inverted the tube with its open end in a vessel containing mercury, he then removed his finger and the column of mercury in the tube descended and, after a few oscillations, it remained stationary, with its top at a height of about 30 inches above the level of the mercury in the vessel at the base of the tube.

It may be concluded, from this experiment, that every surface exposed to the atmosphere sustains a normal pressure equal, on an average, to the weight of a column of mercury whose base is equal to this surface, and whose height is 30 inches.

Now the density of water is to that of the mercury nearly as 1 is to 13·6 ; hence, if a similar experiment were performed with water, the height of the column of water sustained by the weight of the atmosphere would be 13·6 times as much as the height of the column of mercury ; that is 13·6 × 30 inches = 408·0 inches = 34 feet, which is the maximum theoretical height that water will rise to in a pump, but in practice it is found that it will not rise above from 28 to 32 feet.

An instrument constructed on the preceding principles is called a Barometer.

The preceding height, 30 inches, is that at which the mercury stands in the barometer when it is at the level of the sea. Since the weight of the column of mercury balances the weight of the column of air above ; the French philosopher Pascal suggested that if the barometer were carried upwards it would have less weight of air pressing upon it, and therefore there would need less weight of mercury to balance the air, ; this suggestion was acted upon and it was found that the height of the mercurial column decreased as the instrument was carried upwards. It is necessary to apply certain corrections to the barometer when great precision is required ; namely for Temperature, Capillarity, Capacity, Index Error, Reduction to Sea Level, and Unequal Intensity of Gravity.

The words Heat and Cold express well-known sensations, but our sensations do not shew the quantity of heat or cold ; thus if we place one hand in water that is being formed from melting ice, and the other in water as hot as we can comfortably bear, and after keeping our hands in those positions for some time, if we place them in water new milk warm, they will experience very different sensations. The hand which was in the cold water will now experience a sensation of heat, while that which was in the hot water will experience a sensation of cold, although both are in the same water.

This experiment plainly shews that the sensations of heat and cold are modified by the condition of the observer, and consequently they cannot serve as a sure guide to the study of the nature of heat. Recourse must, therefore, be had to some constant standard of reference.

Temperature.—If several bodies, heated to different quantities be placed near each other, an interchange of heat takes place by which they undergo modifications of opposite kinds ; those that are the hottest become colder, and those that are coldest become warmer, and after some time the bodies come to a state of equal heat ; they are then said to have the same *temperature*. If a source of heat be now brought to act upon them they turn hotter and their temperature is said to *rise*, if the source of heat be withdrawn they turn colder and their temperature is said to *fall*.

TWO BODIES IN CONTACT ARE SAID TO HAVE THE SAME TEMPERATURE IF NO HEAT PASS FROM ONE TO THE OTHER.

When two bodies are in contact, if heat pass from one to the other that which gives the heat is said to have the *higher* temperature. Heat always tends to pass from bodies of higher to those of lower temperature.

There are three processes by which heat passes from one body to another, namely, *Conduction*, *Convection* and *Radiation.*

CONDUCTION is the passage of heat through an unequally heated body from a place of higher to a place of lower temperature ; thus if we put the end of a poker into the fire it gradually turns very hot, and the heat gradually passes through the poker, from particle to particle of the iron, until it arrives at the hand that holds the poker.

The heat passes slowly through some bodies, and quickly through others ; the former are said to be *bad conductors of heat*, the latter are said to be *good conductors of heat.* Thus if, on a cold morning, a person get out of bed and step on the rug at his bedside with his naked feet, thence on to the wood floor, thence on to the stone flag at the fire place, and thence place his foot on the iron fender, he will find the floor colder than the rug, the flag colder than the floor, and the fender colder than the flag. The reason of those different sensations is that the rug is a bad conductor of heat, and therefore the heat passes slowly from the foot to the rug, but the wood is a better conductor of heat than the rug, and therefore the heat passes quicker from the foot to the wood than it does to the rug ; in like manner the stone is a better conductor of heat than the wood, and the iron better than the stone.

Hence when we desire to retain the heat in any substance, we use bad conductors of heat ; thus we clothe ourselves with woollen and flannel garments, or the furs of animals, which are bad conductors of heat ; hence also boilers and steampipes are sometimes covered with wood or felt in order that they may retain their heat.

Again, when we desire to receive the heat from any substance we use good conductors.

When heat is applied to a body it produces other effects besides raising its temperature ; it generally alters its volume, or pressure, and in certain cases it changes the state of the body from solid to liquid, or from liquid to gaseous.

CONVECTION.—If we apply heat to the bottom of a vessel containing water, the parts of the water immediately subjected to the action of the heat will expand, and therefore will become lighter and rise to the surface, while the colder and heavier parts at the surface will descend and become heated, and then ascend in their turn ; and thus the process will go on indefinitely. If the water be heated in a glass vessel and some oak saw dust be thrown into the water, then, by the movements of this substance it will be seen that the ascending current occupies the centre of the vessel, while the descending current passes down the sides.

If heat were applied to the surface of the water then the heated portion, being lighter than the colder parts at the bottom of the vessel, would remain at the surface and the top and bottom of the water would never attain to an equal temperature. This fact is exemplified on a large scale in tropical seas, where the fierce rays of a vertical sun warm the surface, but never penetrate to the bottom.

It thus appears that by *Convection* the particles of heated water are *transferred* from one place to another, and carry their heat with them. Convection plays an important part in the heating of buildings by hot water, and in the currents of the ocean, and also in trade and other winds.

IN RADIATION the hotter body loses heat and the colder body receives heat by means of a process occurring in some intervening medium, which does not itself thereby become hot ; thus in a calm day in winter we feel the sun's rays warm even when water is freezing, and ice is hard and dry. The heat which we feel is not conveyed to us by either conduction or convection through the air, for the air is cold and a cold body cannot make another body warmer than itself. The mode in which the heat reaches the body that it warms is called *Radiation.* The distinguishing characteristic of radiant heat is that it travels in rays like light, whence the name radiant.

Heat generally alters the volume of a body and causes it to expand. *The force of expansion of solids* is very considerable, it being equal to the force necessary to compress the body to its original dimensions. Thus, for instance, iron when heated from the temperature of freezing water to that of boiling water increases by ·0012 of its original length. In order to produce a corresponding change of length in a rod an inch square in section, a force of about 15 tons would be required. Hence in the case of structures in which metals are used, the parts are so arranged that the expansion shall not be attended with any bad effects. Thus in a railway the rails do not touch each other, a small interval being left to allow room for the variations of length. Iron bridges, or iron beams used in buildings, must have their ends free to move forward without encountering any obstacles, which they would inevitably overthrow. Sheets of zinc and lead used in roofing are so arranged as to be able, to a certain extent, to overlap each other on expansion.

EXPANSION OF LIQUIDS.—Almost all liquids expand by heat and contract by cold, but water contracts by cold until it reaches its maximum density a little time before it freezes, it then expands so that when it freezes and become ice it is lighter than the water, and floats on the surface.

The expansion of mercury is sensibly uniform between the temperatures of melting ice and boiling water, and this property makes it suitable for the measurement of heat as follows :—

A **Mercurial Thermometer** consists of a bulb and tube of glass which contain mercury ; the tube should be as nearly as possible of uniform bore, and the bore should be very small. A sufficient quantity of mercury having been introduced, it is boiled to expel air and moisture, and the tube is hermetically sealed ; the *freezing point* is ascertained by immersing the thermometer in melting ice, and marking the height of the top of the mercury ; the *boiling point* is ascertained by placing the thermometer in the steam of water boiling under the pressure of 14·7 lbs. on the square inch, and marking the position of the top of the column of mercury ; the interval between these two points is divided into 180 equal parts called degrees for *Fahrenheit's* scale, which is the scale generally used in England, and into 100 degrees for the *Centigrade* scale, which is the one generally used on the Continent ; and similar degrees are marked below the freezing point, and above the boiling point, if necessary.

In Fahrenheit's scale zero, or 0°, is 32° below the freezing point, and the boiling point being 180° above the freezing point, it is therefore marked 212°.

In the Centigrade scale zero, or 0°, is at the freezing point, and the boiling point being 100° above the freezing point it is therefore marked 100°.

TO EXPRESS FAHRENHEIT'S DEGREES IN CENTIGRADE DEGREES, AND CONVERSELY.

RULES.

$$C = \frac{(F - 32) \times 5}{9} \quad \dots\dots\dots\dots\dots\dots \quad A$$

$$F = \frac{C \times 9}{5} + 32 \quad \dots\dots\dots\dots\dots\dots \quad B$$

Where C = number of degrees Centigrade, F = number of degrees Fahrenheit.

EXAMPLES.

1. Express 74° F in C.

By Rule A.

$$\begin{array}{r} 74\ F \\ -\ 32 \\ \hline 42 \\ 5 \\ \hline 9)210 \\ \hline 23\frac{3}{9} \end{array} = 23\tfrac{1}{3}^\circ\ C. \text{ Answer.}$$

2. Express 34° *C* in *F*.

By Rule *B*.

$$\begin{array}{r} 34^\circ\ C \\ 9 \\ \hline 5)306 \\ \hline 61\frac{1}{5} \\ 32 \\ \hline 93\frac{1}{5}^\circ\ F.\quad \text{Answer.} \\ \hline \end{array}$$

Unit of Heat, or Thermal Unit is that quantity of heat which corresponds to an interval of one degree of Fahrenheit's scale in the temperature of one pound of pure liquid water, at and near its temperature of greatest density ($39^\circ{\cdot}1$ Fahrenheit).

The Capacity of a Body for Heat is the number of units of heat required to raise that body one degree in temperature.

The Specific Heat of a Body is the ratio of the quantity of heat required to raise that body one degree, to the quantity required to raise an equal weight of water one degree.

Sensible Heat is heat employed in producing elevation of temperature; hence it affects the thermometer.

Latent Heat means a quantity of heat that has *disappeared*; it having been employed to produce some other change than elevation of temperature; hence it does not affect the thermometer. When a piece of ice below the temperature of 32° *F* is brought into a place, say a room, where the temperature is much higher, the heat of the room enters into it, and gradually raises its temperature to 32° *F* and it then begins to melt; so that when it is nearly all melted the water thus produced must contain more heat than the ice did when it began to melt, but until the ice has all melted, the temperature remains at 32° *F*, the same as when it began to melt; the heat that has disappeared is called the *latent heat of water*.

The latent heat of water can be approximately determined by the following experiment. Take a pound of ice at 0° *C*, and a pound of water at 79° *C*, pour the water over the ice and stir the mixture rapidly, the ice will melt and two pounds of water at 0° *C* will be obtained. This experiment shews that all the heat necessary to raise a pound of water from 0° *C* to 79° *C* has been absorbed in melting a pound of ice; and it is thus proved that the heat required to melt a pound of ice is exactly the same as that required to raise the temperature of a pound of water from 0° *C* to 79° *C*.

If a vessel, full of water, exposed to the open air, and produced from melting ice, and therefore at a temperature of 32° *F*, be placed on a fire the temperature will gradually rise to 212° *F*, and then the water will boil, but it will not rise to any higher temperature than 212° however long the fire may be applied.

A great many solid bodies are in a state of transformation into the gaseous state at their free surface. Ice, for instance, is continually being transformed into the gaseous state at its surface.

The particles of the body thus transformed are called *vapour*. And the process is called *evaporation*.

Steam is an invisible elastic gaseous body generated from water by the application of heat.

If great heat be applied long enough to water, the water will be all evaporated and will become steam.

The heat which has disappeared in evaporating the water is called the *latent heat of steam*.

Experiments, carefully made, have shewn, that 966·6 units of heat become latent in the conversion of one pound of water at the temperature of 212° *F* into one pound of steam at the same temperature.

Watt used the term " free heat" to indicate the amount of sensible heat above 32° *F*, as measured by a thermometer, and he announced the law : that in steam at any given temperature " *The sum of the latent heat and the free heat is a constant quantity*." This constant quantity is sometimes called the *total heat*.

For instance :

	Units.	
One pound of steam at 212° *F* condensed at 32° *F* gives out	180°·0	sensible heat
	966·0	latent heat
Sum	1146·6	total heat

Again :

	Units.	
One pound of steam at 240° *F* condensed at 32° *F* gives out	208°	sensible heat
	938·6	latent heat
Sum	1146·6	total heat

On Boilers.—Before being used boilers should be tested by subjecting them to much greater pressure than they will have to bear while they are in actual use. Hydraulic pressure is commonly employed for this purpose.

Even after being tested it sometimes happens that very disastrous explosions occur, owing either to excessive pressure, or to the boiler becoming weaker.

Excessive pressure is guarded against by safety valves, which allow the steam to escape whenever the pressure exceeds a certain limit, and by guages which show what the pressure of the steam is at any moment.

Safety valves afford ample protection against the danger arising from gradual increase of pressure; but they are liable to fail when there is a sudden generation of a large quantity of steam.

This explosive generation of steam may arise from various causes; for instance if the water in the boiler should happen to fall below a certain level, the sides of the boiler may become heated to so high a temperature that when more water is admitted it will immediately be converted into steam on coming into contact with the hot metal.

Hence it is necessary to keep the water above a certain level. The following means are used for this purpose.:—

1. Two cocks are placed, one a little below the level at which the water should stand, and the other a little above it; those cocks are opened from time to time, when water should issue from the first and steam from the second. Sometimes another cock is placed at the level of the water, and when it is opened there should issue a mixture of water and steam.

2. The WATER GUAGE is a strong, vertical glass tube, having its ends fitted into two short tubes of metal, one proceeding from the steam space, and the other from the water space; the level of the water is therefore the same in the guage as in the boiler, and it is constantly visible to the engineer who has the watch. The metal tubes are furnished with cocks which can be closed if the glass tube be accidentally broken.

Another cause of the explosive generation of steam is the incrustation of the boiler with a hard deposit due to the impurities of the water employed. This crust is a bad conductor of heat, and it allows the portion of the boiler covered with it to become overheated: when there is great danger of explosion if water should find its way past the crust and come in contact with the hot metal.

A HYDROMETER is an instrument used for determining the densities of liquids by observing either the depth to which it sinks in the liquid, or the weight required to be attached to it to make it sink to a given depth. When the hydrometer is specially adapted for determining the quantity of salt in a marine boiler, it is called a *Salinometer*.

Sea water has about $\frac{1}{32}$ part salt, which is about 5 ounces of salt per gallon of sea water; hence, water that has $\frac{2}{32}$ part salt has twice the quantity of salt in it that sea water has, that is, it has 10 ounces of salt per gallon of water; in like manner water that has $\frac{3}{32}$ part salt has 15 ounces of salt per gallon of water and so on.

A SALINOMETER consists of a hollow metal ball, used as a float, with a stem, square, or rectangular, in section, rising from it, and another smaller ball underneath it, containing mercury or small shot to steady the instrument, and cause it to float with the stem upright.

The stem is graduated as follows; it is dipped all over in distilled water heated to a temperature of 200° *F*, and then let float, and the stem is marked at the level of the water; then a quantity of sea water is heated to 200° *F*, the salinometer is then placed in the water, and the level of the water is noted on the stem, one face is marked $\frac{1}{32}$ for the degree of salt in the water, and another face is marked 5 for the number of ounces of salt in a gallon of sea water.

Again: another quantity of sea water is taken and boiled until there is exactly half the quantity of water left, which must contain twice the quantity of salt that sea water does, for heat only evaporates the water, it does not evaporate the salt; bring the water to 200° *F* and mark the level of the stem as $\frac{2}{32}$, and 10; and so on.

The saltness of the water in the boiler is tested by taking a little out of it, and bringing it to the temperature of 200° *F*, and then placing the salinometer under the surface of the water, and then let it float. If the surface of the water be at less than $\frac{2}{32}$, the water is not too salt, but if it be at more than $\frac{2}{32}$ it is too salt.

Seaward's Salinometer consists of a glass tube about 14 inches long, fixed to the boiler and fitted with two cocks in a similar manner to the glass water guage, so that the water in the tube rises to the same level as the water in the boiler; the cocks are then turned off, and another one at the top of the tube opened, through which two small balls of glass or metal are dropped into the water; the specific gravity of the first ball is such that it will sink when there are five degress of saltness in the water, but it will swim when there are more; the other ball will sink when there are less than three degrees of saltness, but it will swim when there are four or more.

The Thermometer may be used as a salinometer as follows: Take water out of the boiler and boil it in an open vessel in the engine room, then immerse a thermometer in the boiling water and note the temperature, compare it with the following table, and thus ascertain the degree of saltness.

BOILING POINT OF WATER.

BAROMETER AT 30 INCHES.

	Saltness	Boils at
Pure water	0	212°
Sea water	$\frac{1}{32}$	213·2
	$\frac{2}{32}$	214.4
	$\frac{3}{32}$	215·5
	$\frac{4}{32}$	216·7
	$\frac{5}{32}$	217·9
Saturated with salt	$\frac{12}{32}$	226·1

Hence, if we would preserve the water of the boiler at a degree of saturation indicated by $\frac{2}{32}$ part of salt, we must blow out one-half of the feed water, if at $\frac{3}{32}$ then blow out one-third, if at $\frac{4}{32}$ blow out one-fourth; and so on. $\frac{3}{32}$ is the highest degree of saturation that should be permitted; the degree of saturation should be tested every watch.

The following table shews the height of the boiling point in Fahrenheit's scale at different heights of the barometer:—

Barometer	Boiling point	Barometer	Boiling point
27 inches	207°·0	29½ inches	211°·2
27½ ,,	207·8	30 ,,	212·0
28 ,,	206·7	30½ ,,	212·8
28½ ,,	209·6	31 ,,	213·6
29 ,,	210·4		

ANSWERS TO THE ELEMENTARY QUESTIONS.

1. The parts which are easily forged and have to bear shearing, torsion, or tensile strains ; such as piston, connecting, slide or eccentric rods, shafting, etc.

2. The parts not easily forged and not subject to strains in various directions, such as cylinders, columns, bed plates, pumps and slide valves, hotwell, etc.

3. The parts which are sometimes made of steel, are piston and connecting rods, main shafting springs, etc.

4. The parts which are made of brass, or gun metal, are the main bearings, connections, rod brasses, liners, buckets, and valve grating for pumps, all cocks, and in places where much wear takes place.

5. In the main bearings, tunnel bearings, guide blocks, and connecting rod bearings. It is adopted on account of its anti-frictional properties. The objection to it is that, owing to it having a very low melting point, should the bearing become heated, it will run out.

6. For bolts, studs, nuts, etc., that are subject to the constant action of salt water, it is also used for condenser tubes and tube plates. It is malleable, strong, durable, and is not liable to corrode.

7. The iron first produced from iron ore is cast iron, and it contains carbon, silicon, phosphorous and other impurities. Wrought iron is cast iron puddled, and it is nearly free from carbon and other impurities. Steel is best wrought iron with 2 per cent. of carbon added.

8. By the difference in the grain. Cast iron is of a chrystaline grain, and is short and brittle. Wrought iron is fibrous and of great tenacity. Steel is fine, chrystaline, is hard, and has less tenacity than wrought iron.

9. Cast iron and steel are both fusible, and are therefore fit for castings. Wrought iron and steel are malleable, and will weld. Steel can also be tempered.

10. The strain necessary to break any material is called the "breaking strain." The strain that any material has been subjected to without causing any permanent rupture is called "proof strain." The strain that can safely be put upon it is called "safe working strain." The proof strain ought to be $\frac{1}{3}$ of the breaking strain, and the safe working load about half the proof strain.

11. The cohesive and breaking strength of good ordinary wrought iron is about 50,000 lbs. per square inch.

12. Heat the steel blood red, then dip it in oil or water, then withdraw it as the red colour give place to straw colour. The colours come in the following order; light yellow, dark yellow, light blue, dark blue. When the right colour appears, immerse the steel in the oil or water, until it is cold.

13. Case hardening is the art of giving wrought iron a hard skin, in order to diminish the wearing of those parts subject to friction. The article to be case hardened is placed in an iron box together with charcoal, bonedust, and leather scrap, then hermetically sealed and placed in a slow fire, sufficient to keep it red hot for 24 hours. The slide valve reversing gear is case hardened.

14. The metals and alloys that can be forged are wrought iron, steel, copper, and muntz metal. Brass, cast iron, white metal, zinc, and tin, are short and brittle.

15. Welding two pieces of iron or steel together is done by heating them to a white heat, and then by hammering them well, until they unite and form one piece.

16. All metals expand with heat and contract with cold; thus a brass winged valve just fitting to its seat when cold will be found tight when heated. Boilers expand considerably under heat; furnace fronts are flanged to allow for expansion, for the same reason fire bars are left a little short.

17. Staffordshire plates are used for shell plates, furnace bottoms and domes. Yorkshire plates are used for furnace tops, back tube plates and combustion box.

18. Double rivetting is the use of two rows of rivets in one seam. In the common flat boiler the bottom and longitudinal seams are double rivetted. And in the circular boiler the longitudinal seams, and often the circumferential one, are double rivetted, but generally when the circumferential ones are double rivetted, the longitudinal ones are treble rivetted.

19. Caulking is the art of closing the edges of the joints, or seams, with proper tools until they are steam and water tight; the edges are either chipped, or planed, before being caulked.

20. The main stays of a boiler are sometimes fitted with nuts and washers on each side of the plates, the ends being larger than the body of the stay, to allow for the screw. The advantage of this method is, that the stay can be very equally adjusted. The disadvantage is, that the stays are too close to allow for examination. Another method is

to have eye bolts secured with nuts to the plates, the stays themselves having double eyes to take the eye bolt, and secured by means of a pin, or cotter. The advantage of this method is that they can be easily disconnected for examination. The disadvantage is that it is difficult to get them all equally adjusted. Another method is to have a pair of angle irons rivetted to each end of the boiler, and using stays, square in section, the stay ends having single eyes to take the angle iron, and secured by a pin and cotter. The advantage of this method is that it gives more room for examination ; for the angle irons assist to stay the plate. The disadvantage is that it is difficult to adjust the stays equally.

21. The greatest strain should not exceed 5,000 per square inch of section at the smallest part of stay.

22. A rivetted screwed stay is a piece of iron screwed the full length, and then screwed into the plates forming combustion chamber sides and shell of the boiler, and the ends rivetted over to form a head ; they are used in the narrow water spaces of the boiler.

23. Thin plates are usually found where the action of the flame is the greatest, and where the parts are alternately wet and dry ; they can be detected by sounding with a hammer, or by drilling a hole through.

24. Boiler tubes are fixed after being pushed through into the tube plate, then the ends expanded by means of a drift or tube expander. Stay tubes serve the purpose of stay and tube combined, they are generally screwed into the back tube plate, and secured by nuts on each side of the front plate.

25. At the combustion box ends. By re-expanding. The leakage is caused by the tube ends being burned, through the constant action of the flame upon them.

26 Cracked tube plates are often caused by salt gathering on the plates round about the outside of the tubes, or by opening the smoke box doors suddenly, thus cooling the plates and causing contraction. The cracks are generally found running from one tube hole into another. They are repaired by drilling holes, tapping and plugging the same, the length of the crack, or by placing a piece of plate over the same and securing it to the tube plate by tap bolts.

27. A dry uptake is a sheet of iron caseing outside of the boiler. A wet uptake has a passage way up through the water and steam space of the boiler, thus being surrounded by water and steam. The dry uptake requires little repairing. The wet uptake requires most repairing because it has to bear the pressure of the steam, and the corrosive effect of the water and steam.

28. A super heater is a vessel through which the steam passes on its passage from the boiler to the engine. It is usually placed in the uptake, so as to receive the heat from the fires on its passage to the funnel, which otherwise would be wasted. It is generally made cylindrical. A steam stop valve, a safety valve, and a drain cock leading to the hotwell is fitted to it, also a glass guage to show whether it is clear of water, as priming may occur.

29. The first parts that are injured are the combustion chamber top, and the highest row of tubes.

30. Angle irons are generally used in rectangular boilers, to join the shell and end plates together, and to join the stays and plates. In cylindrical boilers the plates are all flanged.

31. Priming arises from the pressure being drawn off the surface of the water in the boiler, and thus enabling the ebullition to go on with greater violence. There are many causes, such as want of steam space, excess of tube surface, badly arranged boilers, muddy water, and other foreign substances, becoming mechanically mixed with the water, or it may be caused by irregular feeding or firing. It may be prevented by injecting tallow, or easing the draft of the fires. It may cause the breaking of the cylinder cover, or the bottom of the cylinder.

32. Draft is caused by the expansion of air by heat, by which means part of the heated air is expelled in the funnel, and heated air being lighter than cold air, the cold air from outside forces the heated air up the chimney, thus causing a constant current of air while the fires are in action. It can be regulated by means of a damper which is frequently placed in the funnel, or by closing the ashpit dampers.

33. Flame issuing from the chimney top is caused by a bad supply of air to the furnaces ; it may be caused by having the fire too thick on the bars, thus preventing a a proper supply of air in the combustion chamber. It is highly detrimental to the funnel and causes a great waste of fuel.

34. A blast pipe is a pipe leading from the boiler to the funnel. The end next to the boiler is attached to a cock secured to the boiler, to regulate the force of the blast; the other end is conical and turned up in the funnel. It is used to increase the draft.

35. Two bottom blow-off cocks are generally fitted to each blow-off pipe, one on the boiler, the other on the ship's bottom. In case of an accident happening to the pipe, sea water can be excluded from the sea, or steam from the boiler.

36. The spanner guard is to prevent the key from being removed unless the cock is closed.

37. Test cocks are placed on the end of the boiler next to the engine room. The centre one is placed at the water level or about nine inches above the highest part of the combustion chamber. Other two are placed, one six inches above the centre one, and the other six inches below it. The cocks are better at those heights so as not to require internal pipes. A small plug is provided at the bend of each cock, by unscrewing this plug a pricker can be inserted to clean the passage way of the cock.

38. A dead safety valve has the required weight placed directly upon it. The rubbing surfaces are made of brass. The spindle of the valve is fitted with a cast iron cap with cross handles on, a flat key passes through it and the spindle, the key space is made so that the valve can be turned round or lifted up, so as to allow a free escape of steam, but it effectually prevents any more weight being added to the valve.

39. The area required by the Board of Trade is ½ a square inch for 1 square foot of fire grate surface. Sudden opening of the valve would cause priming. The valve would lift about $\frac{1}{64}$ of an inch, but the greater the pressure on the boiler the higher is the lift.

40. One advantage of the spring safety valves is that the pressure is uniform and constant, whether the vessel be upright, or heeling over, thus effecting a saving of fuel and steam. Another is that there is no liability to stick when the vessel heels over. The disadvantages are that the spring may lose its elasticity in course of time, or it may be faulty in its construction.

41. A glass water gauge is composed of two brass stuffing boxes fitted with cocks attached to the boiler, and a strong glass tube with its ends secured in the stuffing boxes. When the two cocks are open to the boiler, the water level in the boiler can speedily be seen; there is also a small drain cock attached to the lower part of the guage to blow the glass clear of all sediment that may accumulate in the glass. It is placed on the front, or back, of the boiler where it is best seen and accessible, the bottom end of the glass should be at least three inches above the highest part of the flame box. The glasses are liable to burst, or become choked with sediment. It can be tested by means of the test cocks.

42. The object of having pipe connections with top and bottom of a boiler to a glass water guage, is to have a steady and clear water level shown in the glass. There should be cocks at the extremities of these pipes in case of accident to the guage or pipes.

43. The principle involved in the construction of dial steam guages is, that a thin elliptical metal tube if bent into a ring, will seek to coil or uncoil itself if subject to external or internal pressure and in proportion to that pressure. A Bourdon steam guage is on the above principle, connected at one end to a pipe leading to the boiler, the other end being

connected by a link to a quadrant gearing with a small pinion and a pointer attached, which indicates on a graduated index and shews the pressure of steam. The inverted syphon pipe is placed under the guage to contain a little water to prevent the heat of the steam from injuring the working parts of the guage.

44. A small cock on the pipe of a steam pressure guage is necessary in order to clear the pipe from the water which may have collected in it. It should be placed at such a height so that a column of water in one leg will equal the column of water in the other, otherwise the correct pressure would not be indicated.

45. Steam guages do not indicate the total pressure, only the pressure above the atmosphere; the total pressure is about 15lbs. per square inch more than the steam pressure.

46. By the salting of a boiler is meant the accumulation of salt on the tubes and other heating surfaces of the boiler. It is prevented by scumming, or blowing off, occasionally, so that not more than $\frac{2}{33}$ of the water shall be salt. The density of sea water is 1·027. It may be ascertained by means of the Hydrometer or Salinometer. The density of the water in the boiler while working should be kept at 1½ — 33 to 2 — 33rds.

47. The scum cocks and pipes are so arranged that the surface water can be cleared of sediment and other impurities and blown into the sea. One cock is fitted to the boiler a little below the working water lever with an internal pipe with a dish end to it reaching up to the working water level, the other cock is fitted on the vessel's skin, and the two connected by a copper pipe. They are used when the boiler water has attained $\frac{2}{33}$ of saltness, or when there is reason to think that there is dirt on the water surface. They must be shut before the water in the boiler has got too low. Neglect of the cocks would lead to the danger of burning the tubes, and salting the boiler.

48. Scale consists of salt and lime. It is most objectionable on the parts of a boiler that are exposed to flame or heat. It can be removed by chipping with long chisels made specially for the purpose. It can be prevented by regular blowing off before the water has become too salt, or by suspending zinc plates in the boiler. Scale on a boiler causes loss of fuel, burnt plates, leaky tubes, and danger from explosion.

49. The Salinometer is an instrument for indicating the density of water. It consists of a hollow bulb of glass, or metal with a graduated stem at the top, and a balance stem at the bottom so as to make it swim upright. Its action is to sink deeper into water of little density, and float lighter as the density increases. It is graduated to 32nds, which equals about four ounces of salt or other impurities, to a gallon of water. It can only be used in water at the temperature for which it was graduated.

50. Division plates are to prevent the water from rushing from one side of the boiler to the other while the vessel is rolling heavily, and leaving the one side of the boiler tubes dry. The plates are not made steam nor water tight. They stand fore and aft.

51. The leak from a split tube is stopped by driving in a wooden plug into the leaky tube past the leak, and then driving in a second one, thus both ends of the tube are stopped, and hence the leak is stopped. There are other methods, but the above generally is resorted to when at sea.

52. Dampers are used to check the rush of air through the furnaces. They are fitted in the funnel or before the ashpits. They should be used when priming occurs, or when steam is being generated too fast.

53. When there are no dampers fitted, the furnace and smoke box doors are opened. The evil is that owing to the too sudden contraction by the rush of cold air against the tube plates, they are liable to split.

54. The piston commonly used for marine steam cylinders, consists of a large circular casting, cored out and stiffened by means of ribs on the flat surface ; it has a large tapered hole in the centre so as to secure it to the piston rod, there is a flange on the outer part just fitting the cylinder for the packing ring to rest on, which is a cast iron ring, cut so as to allow it to be sprung out against the sides of the cylinder, by means of steel springs ; to prevent steam passing where the ring is cut, a brass tongue piece is fitted also allowing the ring to be sprung against the sides of the cylinder. The round pieces let in flush on one side of the piston are tapered, or screwed plugs, to fill up the holes that were necessary to support the cores in casting.

55. Cylinder drain cocks are used to drain off any water that may have gathered in the cylinders through priming or condensation. The valve upon the drain cock is to prevent water, or air, from being forced by air into the cylinder while a vacuum is formed in the cylinder.

56. Cylinder escape valves consist of a brass valve and seat being loaded with a helical spring; they are often fitted at the top and bottom of cylinders. They are protected by a cast iron casing which fits over the top of the valve and spring. They are regulated by means of a screw which passes through the top of the cover which is tapped. These valves are most needed when starting the engines or when the boilers are priming, so as to allow any water to pass out from the cylinder. The engineer is exposed to the danger of scalding if the precaution is not taken to direct the water away from the front of the engines.

57. A compound engine is a combination of a high and low pressure engine, having for its object the utilizing of the expansive property of steam; the mechanical power of steam is commenced in the high pressure cylinder and finished in the low pressure cylinder, from which it is exhausted into the condenser. There are several different kinds of arrangements used for marine purposes; the most general is that where the high and low pressure cylinders are bolted together, the steam chest being between, and connected direct with the cranks on the shaft. Another arrangement is to have the high pressure cylinder above the low pressure cylinder connected with one piston rod. Another arrangement is to have two high pressure cylinders and two low pressure cylinders, the high pressure cylinders being above the low pressure, connected direct with two cranks to the shaft. There are other arrangements, but these are the most general in use.

58. The link motion is a contrivance of slide valve gear so that engines can be easily reversed and the rate of expansion varied at pleasure. It consists of two eccentric sheaves and straps and rods, attached at the ends of the rods by radial links, upon which travels the block which is secured to the valve spindle end. To enable either of the eccentric rods to come in a direct line with a valve spindle, thus giving motion to the engines to go either ahead or astern. The advantage of this motion is its simplicity of construction, and the ease and readiness with which it can be used. When there is no link motion the single but lose eccentric is used.

59. A separate expansion valve is a slide that works independently on the back of the main slide valve for the purpose of cutting steam off at an earlier part of the stroke. It is not fitted to all engines, since sufficient expansion may be got by lap on the main slide, the extra complication and gear not compensating for the small amount of fuel saved in small engines. The effect of an expansion valve is often to hinder and retard the reversing of the engines.

60. The arrangement often used for reducing the friction of a slide valve consists of a brass ring, truly faced, and fixed on the back part of the valve, about equal to the area of the exhaust passage on the valve, and kept pressing on a plane surface on the jacket door by means of springs or india rubber; this causes a space to be left behind the valve, which is in communication with the condenser, and so forms a vacuum, thus diminishing friction to a great extent. The friction of a slide is due to the pressure of steam acting upon the unbalanced area of the slide valve.

61. A loose eccentric is an ordinary eccentric fitted with balance weights and stops for going ahead and astern. It being loose on the shaft it can be moved partly round the shaft against the stops, which are placed in such a position as to give the necessary amount of lead and cut off for going ahead or astern. The eccentric rod has a gab end to it to engage with a pin on the valve shaft; by lifting the gab from the pin the slide valve is free to move by the hand lever for starting purposes; after starting the gab is engaged with the pin, thus working the valve. The link motion is used instead.

62. The travel of the eccentric rod is the distance the rod moves up and down in a direct line. It is measured by taking twice the distance from the centre of the shaft hole to the centre of the eccentric sheave.

63. Double beat valves are so contrived as to have the pressure on both sides of the valves, thus keeping it in equilibrium, and being easy to move. They are not used for safety valves on account of their unequal expansion, which would entail a waste of steam. They are sometimes used as slide valves, being worked by means of a cam. The objection to their use as slide valves in quick moving engines is that the mitres would not last long, thus becoming leaky and requiring a great deal of attention.

64. A circulating pump is used for circulating cold water through the condenser tubes, thus condensing the steam from the engine by coming in contact with the cold tubes. It is not always worked by the main engine; sometimes it is worked by a small auxiliary engine.

65. An air valve is fitted to a circulating reciprocating pump to admit a small quantity of air to cushion the otherwise solid resistance offered by water.

66. The difference between a bucket air pump, a piston air pump, and a plunger air pump, is: the bucket air pump is a single-acting pump, and has a piston with a space round the circumference to receive rope packing; it has perforations to admit water passing from one side to the other on the top side of the bucket, and over the perforations, is an India rubber fall, secured by a guard, to allow the required lift and to keep it in its place; it is fitted with head and foot valves. A piston air pump is a double-acting pump, and has a solid piston fitted with a junk ring and packing rings; it has suction and discharge valves at each end of the pump. A plunger air pump is single acting, and consists of a long ram, or plunger, passing through a gland, or stuffing box; it has one suction valve and one discharge valve.

67. A double-acting air pump is made with a solid piston, fitted with junk and packing rings.

68. An air pump trunk is a hollow cylinder connected with the bucket or piston, and passing through a stuffing box and gland in the air pump cover. It is rendered necessary when the space in which it has to work will not admit of a pump crosshead and links. The difference in the discharge is equal to the difference of the volume of an air pump trunk and air pump rod.

69. Double-acting air pumps require suction and discharge valves, but it is possible to do without a foot valve, or a head valve, in the case of a bucket air pump.

70. An air pump with a discharge valve and no foot valve would be most affected by a leaky stuffing box. For this reason, in the act of the pump finishing the discharge a little air might get in on the top of the bucket valve, and then prevent the bucket valve readily rising off its seat on the down stroke.

71. In the case of the rod or trunk passing through the delivery valve a leaky stuffing box will not make any sensible difference with or without a foot valve, but if the delivery valve be on the side of the pump, unless there be a foot valve, there will be a loss of work, consequent on the loss of vacuum, thus causing the pump not to work.

72. Air pump pet cocks or valves are placed under the head valve. To admit a little air, the elasticity of which prevents the heavy thud of water that would otherwise occur. They necessarily diminish the effective capacity of the pump. They are not equally applicable to double acting pumps, as the air reduces the effective capacity of the pump.

73. The water in the hotwell of a surface cendensing engine is generally worked at a temperature from 100° to 130° Fah. The effect of a higher temperature would destroy the air pump India rubber valves. The effect of a lower temperature would involve an increased comsumption of fuel. The temperature of the sea water limits the lowness of the temperature of the hotwell. The disadvantage of a low temperature is that the feed water would be cold, and so require more fuel to generate it into steam.

74. The fittings required for a bilge injection with common condenser is a non-return valve on the condenser with a lead pipe with strum on the end leading to the bilge. It is used only when the bilge pumps are unable to keep the bilges clear of water. Great care is required to keep dirt from entering the air pump. By regulating the sea injection the condenser is kept at the working temperature.

75. When surface condensers are used the non-return valve is fitted to the circulating pump, so that the bilge water may be used for purposes of circulating water. It is necessary to have a non-return valve, so that the water when it has passed the valve shall not return into the bilge on the down stroke of the pump.

76. Injection cocks are regulated by handles or levers. The practical guides to the proper amount of opening is by observing the vacuum guage and the temperature of the condenser: if there is a low vacuum then the temperature of the condenser is too high, it requires more injection water; or if the temperature in the condenser is too low it will require less injection water.

77. The feed pump pet cock or valve is placed between the suction and discharge valves. Its use is to indicate whether the pump is working properly or not. It acts by means of the atmospheric pressure pressing on it from the outside, while a vacuum is formed on the

upstroke of the pump. It is a necessary fitting, as it prevents the heavy clattering of the brass valves, and so preserves the mitres ; also it prevents the heavy shock that would otherwise come on the discharge pipes.

78. The most common method of securing the ends of surface condenser tubes is by driving compressed wood ferrules in between the tubes and the plates, and allowing the wood ferrules to expand by water. Another method is to have the ends of tubes extending well through the plates and forming a small stuffing box with screwed gland packed with cotton or India rubber washers ; this is an expensive way but very effectual. The tubes are about $\frac{3}{4}$" in diameter, and about $\frac{1}{16}$" in thickness.

79. A blow through valve is an ordinary small valve and chest, with spindle and working lever complete for purposes of blowing through and expelling all air from the engine and condenser before starting. It is attached to the slide valve casing. A valve is sometimes fitted to admit steam from the slide valve casing to the exhaust port. Its use is the same as the blow through valve.

80. A snifting valve is an ordinary brass mitre valve fitted to the condenser. Its use is to allow for the escape of air or water which is required to be expelled from the engine and condenser, and thus causing a partial vacuum before starting. It is fitted to the lower part of the condenser. If it be placed too high the water will accumulate and the condenser would not get relieved. It cannot be placed too low ; the lower it is the better. It should be kept down as low as possible in order to let every particle of water out.

81. The connections generally fitted to hand pumps are to draw from the sea and bilges, to discharge on deck, into the boiler, or overboard. It can be applied to throw water as a fire engine in case of fire.

82. When the engines are stopped, the main steam stop valve, throttle valve, and feed check valves should be closed, the safety valve should be eased, and all dampers closed, the drain cocks should be left open.

83. An engine is heated up before starting by easing the main stop valve, throttle valve and blow through valve. Before starting take the precaution to see that all drain cocks are open and doing duty, see that the main stop valve, throttle, sea injection, main discharge, feed check, and bilge pump discharge valves are all open, and that all parts of the engine are free to move.

84. An interceptor, or catch water, is a square or oblong cast iron chest, containing a diaphragm plate extending half way down from the top, the steam entering from the side at the top, and is intercepted by the plate, thus disengaging the particles of water which may have rushed with the steam from the boiler. The attention it requires is to keep it clear of water, or the passage way for steam may become closed. A drain cock is fitted for this purpose.

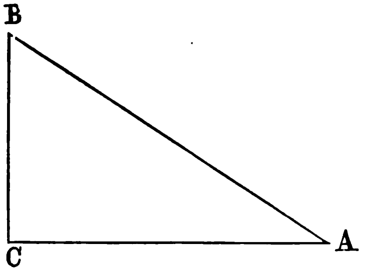
85. An air pump bucket is a hollow brass piston with perforations on the top side to allow water to pass from one side to the other; in the centre is a boss to receive the pump rod, from the boss ribs radiate to strengthen the bucket, on the circumference a space is formed to receive rope packing, on the top side of the bucket and over the perforations is an India rubber fall, secured by a brass guard, which also allows it to have the required lift. The valves are generally made of India rubber.

86. Air pump rods are generally made of muntz metal, or iron, cased with brass. It is done to prevent galvanic action setting in, or to prevent the rods from corroding.

87. The racing of an engine is want of uniformity of motion. It occurs when the propeller is partly thrown out of the water by the sea lifting the stern. It occurs frequently when the vessel is light. The danger attached to it is, the breaking down of the machinery or propeller. To prevent it the governor is attached; if there be none fitted the engineer must stand by the throttle valve and close it as the vessel's stern lifts, and open it when the vessel's stern is down in the water.

88. The marine governor is a contrivance for regulating the speed of the engines at times when they are likely to race. They are variously constructed, but the general principle is the same. Suppose a cylinder be divided into two parts by a line oblique to its axis, and if one part be worked from the shaft, the other part being free to move along its axis, then any sudden increase of speed in the revolutions of the first part, will cause the other part to move along its axis by bringing the longer parts of each together. This motion is communicated to the throttle valve; thus steam is shut off when required, a spring presses the part back again, when the ordinary speed is restored.

89. The pitch of a screw propeller is the distance it would advance in one revolution if working in some unyielding substance. To measure the pitch of a propeller. Let ABC be a triangle, right angled at C, and having the angle BAC equal to the angle of the propeller blade, and let AC be equal to $\frac{1}{8}$th of the circumference of the propeller; then the perpendicular line BC is equal to $\frac{1}{8}$th of the pitch, and the hypothenuse is equal to the breadth of the blade.



90. The difference between a right-handed and a left-handed propeller is, that one goes the opposite way round to the other, or the right-handed propeller revolves from port to starboard, and a left-handed propeller revolves from starboard to port.

91. The slip of a propeller is the loss caused by the yielding nature of the water. It is generally expressed in amount, as so much per cent. loss. The loss varies from 1 per cent. to 25 per cent.

92. The engine and boiler valves that have to be worked by hand are the following—the steam stop, throttle, starting, blow through, safety, kingston and delivery valves, and all cocks. The self-acting valves are the air, circulating, feed and bilge pump valves, cylinder escape, snifting and government safety valves. The main slide valves are worked direct from the engine.

93. In a low pressure boiler tallow is forced in by means of a syringe, but in high pressure boilers it must be forced in by the feed pump along with the feed water ; it is done to allay the violent ebullition of the water. It must be forced into the water space, for if forced into the steam space it would amalgamate with the steam and rush into the engines, thus avoiding the purpose it was intended for.

94. The tallow cup, with top and bottom cocks, is most suitable for H.P. engines. The one with one small cock, or large hollow plug cock, or one with small cock and valve are suitable for condensing engines. The tallow cup with one cock is used thus—the cup is filled with tallow, and the cock kept shut until a vacuum is formed on the top side of the piston, then it is opened and the tallow is forced in, after which the cock is closed again.

95. A cylinder escape valve, self-acting, does not allow all the water to escape, the quantity of water left will be equal to the clearance between the piston and the cylinder cover or bottom.

96. A steam lubricator, or impermeator, is a contrivance for mixing the steam with oil, so as to keep the piston and slides regularly lubricated. It is arranged so that the steam rising up a tube and coming in contact with the colder surface of the lubricator, is condensed, thus the condensed steam mixing with the oil and the water, being heavier than oil, it sinks to the bottom, thus forcing the oil by flowing over and down the tube into the steam chest. It is fitted to the steam pipe or slide valve casing. By throwing cold water over it, it will condense more steam, thus causing the oil to flow down the tube much quicker.

97. The centre of a common paddle wheel is made of cast iron. The arms are formed of wrought iron. The bolts for attaching the floats to the arms are hook-shaped at the end which grips the arm, the other end passing through the float is straight and screwed to take a nut and washer. The arms fit into sockets cast on to the centres and secured by iron cotters.

98. Paddle wheels have one or more cast iron floats in each wheel to act as counter balance to the engine. They are required for single side lever engines. They are placed so that when they are at the bottom the engine has a slight lead on the down stroke for going ahead.

99. Floats are made of different breadths, so that the motion of the engine may be uniform. In single engines with common wheels this is most needed. The broad floats take the water when the engine is at half stroke, the narrow ones when on top or bottom centre.

100. The difference between radial paddle wheels and feathering floats consist in the manner the floats take and part from the water; the former are rigidly secured to the wheel arms, and being radial do not always present a vertical face to the water, whereas the feathering floats are secured by the centres, and attached to them is a rod leading to an eccentric, which always keep the floats in such a position while they take and leave the water that they always present a vertical face to the water. The object of this arrangement is to gain power. The eccentric rods are all of the same form and attached the same way, except the driving rod, which is attached to the eccentric strap, which works on a sheave secured to the vessel's side.

101. The centre of the eccentric of a paddle wheel with feathering floats is placed in advance, but level with the centre line of shaft. When the paddle wheel has an outer bearing the eccentric sheave is made in two halves and bolted to the ship's side, sometimes it is cast on to the outer bearing.

102. The pins upon which the floats turn are made of brass, and the bushes where the pins turn in are fitted lignum vitæ. They are all lubricated by water thrown up by the wheel.

103. A disconnecting paddle engine is a double engine, arranged so that both engines can be worked together or separately. It is effected at the crank pin. The disconnection is effected by forcing back by a lever or clutch, which slides laterally upon keys fixed in the shaft. This clutch takes the crank pin when in gear, but is disengaged when disconnection is required. The crank pins are fitted in the outer shaft crank.

104. Loose eccentrics are mostly used for disconnecting paddle engines. Those kind of engines are frequently employed where quick turning round of the vessel is necessary, such as tugs, ferries, etc.

105. An expansion joint is a stuffing box with gland complete; they are for purposes of allowing pipes to expand or contract and also for the working of the vessel without risk of fracture. They are necessary for straight leads of pipes, or pipes leading from the boiler to the engine, or from the engine to the ship's side, or connecting two boilers together. They require that the packing be attended to from time to time and the gland be kept free to move. The surfaces in contact should be made of brass.

106. Omitting to fit a collar with check bolts to prevent the pipes being blown apart, might lead to serious consequences. It is prevented, in the case of a trunnion pipe, by fixing to the pipe a bracket, which is secured to the engine frame.

107. An oil cup is a small brass or cast iron box fitted with a lid, and having a syphon pipe in the centre, reaching up to within ⅛" from the top. This pipe leads to the parts which require lubrication. The worsted is freed from twist, and has one end weighted, so as to keep it immersed in the oil. The other end is attached to a wire leading down the tube. The worsted is cleaned by scalding. The worsted down the tube must extend below the bottom of the oil box.

108. A thrust bearing is a cast iron block with recesses to admit of brass collars to be fitted, and within which work a corresponding number of collars on the shaft. It is to take the thrust of the propeller from the engines, and communicate it direct to the hull of the vessel. The fore and aft surfaces of the brass rings wear. Each collar requires an oil tube; thus a number of tubes are required for a thrust bearing.

109. The parts of a screw shaft generally covered with brass are where the lignum vitæ bearing, and the stuffing box bearing is required. It is necessary to preserve the bearings from corrosion. The thickness of the brass is about ⅛".

110. The stern tube is a strong cast iron tube or pipe, secured at the stern post and the after bulkhead, and within which the screw shaft revolves. The length is required on account of the narrow part of the vessel through which it passes, and so as to reach the after bulkhead. It is made of cast iron or cast brass. The end next to the after bulkhead is secured by means of a flange cast on, and this being bolted to it. The after end is secured by means of a large nut, the tube itself being screwed for the purpose.

111. A lignum vitæ bearing is a brass bush fitted with strips of lignum vitæ wood. They are fitted dovetailed, and secured by means of a checkplate. This kind of bearing is generally used in stern tubes and outer bearings.

112. The propeller is carefully fitted to the cone end of the shaft, and secured by feather keys sunk in on the shaft, and double nuts on the end. A checkplate is used to prevent the nuts from unscrewing.

113. Sluice valves are placed on water-tight bulkheads, on both sides of the vessel. A large sluice valve is always fitted at the entrance to the tunnel from the engine room to enable the engineers to have free access to the tunnel. This sluice valve should be worked from the top platform, so that, in case of an accident happening, it could be closed easily. The attention it requires is to keep it in thorough working order.

114. The valves and cocks on the skin of the vessel with condensing engines are the following:—In the engine-room, the main injection, main discharge, and bilge discharge valves, and a cock for water service for bearings. In the stokehole are the bottom blow-off, scum, and cooling cocks.

115. The necessary fittings of a marine boiler are:—The safety, steam stop valves, bottom blow-off, and scum cocks, feed check valves for main engine and donkey, the water guage glass and fittings, test and salinometer cocks.

116. With a surface condensing engine the following valves and cocks are opened before starting. The steam stop valve, the main injection and the main discharge valves, all drain cocks to allow waste water to escape, feed check valves and water service cock.

117. A steam jacket is a casing round the outside of the cylinder, the casing being supplied with fresh steam from the boiler; it is to preserve the steam in the cylinder from loss of temperature. A drain cock is fitted to drain all waste water away; a cock is also fitted to admit or shut off steam to or from the casing. Jacketed cylinders are generally used in compound engines, and should be well felted to prevent radiation.

118. All steam pipes, boiler tops, superheaters, and cylinders should be felted, or otherwise protected from radiation. All smoke box doors and casings should be cased for the same purpose.

119. The small cylinders sometimes fitted on the slide valve casing cover of vertical engines are for the purpose of counterbalancing the weight of the slide valves and rods below them. The upper end of the slide valve rod carries a piston, which works in the small cylinder, which is open on the bottom to the slide valve casing, and on the top to the condenser by means of pipes; thus the piston has a constant upward pressure, keeping the whole in equilibrium.

120. The principal pipes connected with engines and boilers are:—The main steam pipe connecting the steam stop valve to the throttle valve on the steam chest; the exhaust pipe from the exhaust passage on the cylinder to the condenser; the main injection pipe from injection valve to circulating pump; the main discharge pipe from condenser to discharge valve on the ship's skin; feed suction pipe from hotwell to pump valve chest; feed discharge pipe from pump valve chest to feed check valve on the boiler; bilge pump suction pipes leading to different parts of the vessel, each end having a strum attached; the bilge pump discharge pipe from pump to discharge valve on the vessel's side; the scum pipe from scum cock to cock on vessel's skin; the bottom blow-off pipe from blow cock to cock on vessel's skin; the waste steam pipe from the safety valves to the open air.

121. The water, from the sea injection roseplate, on its way to the water space of the boiler, passes through the injection valve along the injection pipe into the condenser, then through the air pump into the hotwell, thence through the feed suction pipe and valve chest to the feed pump, along the feed discharge pipe, through the check valve into the water space of the boiler.

122. The circulating water of a surface condenser passes first through the main injection valve on the ship's skin, along the injection pipe to the circulating pump foot valve, through the pump and through the condenser tubes, thence through the discharge pipe and valve on the ship's skin into the sea.

123. The steam, in passing from the boiler to the hotwell, where it arrives in its condensed state, passes through the steam stop valve, along the steam pipe, through the throttle valve into the steam chest, through the H.P. cylinder into the L.P. steam chest, thence into L.P. cylinder, then through the exhaust pipe into the condenser, where it is condensed into water; then it passes through the air pump foot valve and pump into the hotwell.

124. The pieces of an engine through which the pressure is transmitted from the piston to the screw propeller are as follow:—The piston, piston rod, crosshead, connecting rod gudgeon, through the connecting rod to the crank pin, thence to the crank and shaft; then to the couplings and bolts along the intermediate pieces of shaft, and couplings and bolts, to the screw shaft and propeller.

125. An air vessel is a cast iron chamber fitted to pumps to secure a more uniform flow of discharge water. Its action is thus:—The chamber is filled with air; then, as the pump forces water through the pipes, the water also enters the chamber, thus compressing the air in it; as soon as the pump is done forcing, then the compressed air forces the water out of the chamber along the discharge pipe; thus a uniform flow of water is maintained. An air vessel is generally applied to all pumps.

126. A mud box is constructed of cast iron, oblong in form, fitted with a hinged lid that may be easily opened, but which must be air-tight when closed. It is divided into two parts by means of a perforated plate, which allows water to pass, but prevents all chips or dirt from passing to the bilge pump. They should be placed where they can be easily looked to and cleaned. They are necessary fittings to bilge pumps, as ensuring clear pipes.

127. A trunk engine has a pipe or round trunk secured to the piston, which moves steam tight through stuffing boxes at each end of the cylinder; piston rod and guides are dispensed with. The object is to reduce the distance between the crankshaft and cylinder, still retaining a good long connecting rod; it must be also large enough to allow for the requisite vibration of the connecting rod. For a right-handed propeller the cylinder should be placed on the starboard side of the vessel, because the oblique strain of the connecting rod, when the engines are

going ahead, will press the piston on to the top side of the cylinder, thus neutralizing, to a great extent, the weight of the piston and trunk, otherwise it would wear the cylinder oval in a very short time.

128. An oscillating engine is an engine so constructed as to be susceptible of vibrating upon two external trunnions. It also enables a connecting rod to be dispensed with. The piston rod being connected direct to the crank, it also allows the piston rod to accommodate itself to the movement of the crank. This kind of engine is generally adopted for paddle steamers, since there is no connecting rod required. It can be placed under the crankshaft, thus economising space and height. The steam is conveyed to and from the slide valve casing through the hollow trunnions.

129. The parts of which the valve motion gear of an oscillating engine consists are:—Two eccentric sheaves and straps; two eccentric rods with radius link attached, in which slides a block attached to the valve sector, and in the slotway of the sector slides another block attached to one end of the valve shaft lever, the other end being attached to the slide valve spindle; this sector is to allow for the oscillation of the cylinder, hence the radius of it must be taken from the centre of trunnions to when the valve is at half stroke.

130. Geared engines are sometimes used for screw propulsion. They are used to increase the revolutions, and at the same time to decrease the piston speed. The cogs of the large wheel are made of particular kinds of wood, such as live oak, beech, hornbeam, etc.

131. The parts of a screw steamer where the pressure is applied to propel the vessel is at the thrust bearing, which is firmly secured to a wrought iron seating, strongly fixed to the hull of the vessel.

132. The part of a paddle steamer where the pressure is applied to propel the vessel is at the paddle beams and bedplates, which are securely attached to the hull of the vessel.

133. For common engines there is required from 4lbs to 5lbs of coal per I.H.P. For compound engines from 2lbs to 3lbs of coal per I.H.P.

134. The explanation of the economy of surface condensers is this:—The feed water is fresh, and returns to the boiler at a good high temperature, thus saving the fuel that would be wasted if the scum had to be kept blowing, as in a common engine, to prevent the water becoming too salt.

135. A surface condenser consists of a large cast iron chamber, each end having a tube plate and tube box with doors attached; the tubes are made of brass, and pass through each plate. The ends are secured in the plates by means of compressed wooden ferrules, which swell after coming in contact with water, thus keeping the tubes effectually tight. A split tube is plugged at both ends, until it can be renewed.

136. Surface condensers foul from grease and oil on the steam side of the tubes, and should the condenser be worked at a high temperature, a deposit of saline matter will occur on the inside of the tubes. They are often cleaned by injecting soda into the condenser, and also, when in port, by taking the condenser end doors off, and inserting a small scraper into the tube and scraping all sediment off; or it may be done by scalding with hot water.

137. The non-conducting substances generally employed are felt, or a cement specially prepared. They are secured with wood or canvas. The surfaces are generally painted, and while the paint is wet the felt is applied to make it adhere; the cement is generally applied about three inches thick, and secured by wood.

138. Provision is made to lessen radiation by smoke-box doors and dry uptakes by means of air casing, standing about 2" from them, which allows the cold air to circulate freely round them.

139. The formation of black smoke can be prevented bv careful stoking, and by admitting a small quantity of air into the combustion chamber. Smoke-preventing apparatus all aim at giving a further supply of air to the furnaces.

140. By circulation in a boiler is meant, the water nearest to the heating surfaces expands and becomes lighter, thus rising to the surface and giving place to the colder water, which, in its turn, becomes heated and expanded, and rises to the surface; thus a constant circulation of water is going on in the boiler. The results of defective circulation are:—Priming, salting, and damaged plates.

141. The means sometimes adopted to improve circulation is by having circulating pipes in some parts of the boiler, which will allow the water to descend freely.

142. The circulation is promoted in haystack boilers by putting cross tubes in the flame box.

143. A ship's side air-pump discharge valve is a cast iron chest, with brass valve and seat fitted, a spindle being attached to the valve, working up through a stuffing-box and gland in the cover; it is weighted so as to keep shut of its own accord. It differs from a common valve inasmuch as it is self-acting, and does not screw up or down, but can be kept up or down by means of a cotter passing through the spindle. The attention it requires is to see that it is perfectly water-tight, otherwise water from the sea would find its way into the hotwell.

144. A feed escape valve is a cast iron chest fitted with a brass valve and seat, having a spindle working up through a stuffing box and gland in the cover. On each side of the spindle is a pillar, the pillars are connected at the top by a plate; the adjusting screw passes through the centre of the plate, the spring is fixed between this screw and the spindle. The discharge is in connection with the hotwell or suction pipes. The loading of the spring is regulated by means of the adjusting screw.

145. With no feed escape valve, the feed check valve has no adjustment, and a cock or valve is fitted on the suction pipe to regulate the suction.

146. The measure of a horse power is the force required to raise 33,000lbs one foot high in a minute. Indicated horse power is ascertained from indicator diagrams taken from engines, by finding the mean pressure throughout the stroke, and by counting the number of revolutions per minute the engine is going. The formula is :—

$$\text{I.H.P.} = \frac{\text{area of piston in inches} \times \text{mean pressure} \times \text{speed of piston in feet per minute.}}{33000.}$$

147. Nominal horse power has no definite meaning, each engine builder having a measure of his own. The expression is only used as a means of comparing different engines.

148. Back pressure means the resistance offered to the piston opposite to the side to which steam is applied. It generally amounts to about 3lbs per square inch.

149. By speed of piston is meant the number of feet travelled by the piston in one minute. It is found by twice the length of stroke × by the revolutions of the engine per minute. The piston speed of modern marine engines is about 350 feet per minute.

150. Atmospheric pressure is the pressure exerted by the atmosphere at the sea level. Its average amount is about 14.7lbs per square inch. The barometer shows it.

151. Gross or absolute pressure is the atmospheric pressure plus the steam pressure. The steam guage shows the pressure above the atmospheric pressure.

152. By the words "cutting off" steam is meant the closing of the steam port by the slide valve, thus cutting off a further supply of steam to the cylinder. It is done by the slide valve. The part of the slide valve which regulates the cut-off is the outer edges.

153. The time of exhausting is fixed by the amount of inside lap given to the valve, and also by the setting of the eccentric sheave. It depends upon the inside edges.

154. The time of closing the exhaust is fixed by the amount of inside lap given to the slide valve. After the exhaust port is closed, and before the port is opened for steam, the steam remains in the cylinder; it becomes compressed, thus forming a cushion to the piston at the end of the stroke.

155. The lead of the valve is the measured amount that it is open when the engine is on its top or bottom centres. The object is to pre-

serve uniformity of action, so that the piston may come to a state of rest gradually, and also that the engine may commence its stroke with pressure about $\frac{1}{16}''$ on the top and $\frac{1}{4}''$ or $\frac{3}{8}''$ on the bottom.

156. The "cover" or "lap" of the slide valve is the measured amount which the outer edge of the valve overlaps the steam port, with the valve standing in mid position. Its object is to cut off the steam from the cylinder at a given part of the stroke, thus allowing the remaining part of the stroke to be accomplished by expansion of the steam. A good proportion is about $\frac{1}{3}$ of the stroke of the valve, but it all depends upon the cut off required.

157. "Exhaust cover" or "exhaust lap" of a slide valve is the measured amount which the inside edge of the valve overlaps the steam port with, the valve standing in mid position. It increases cushioning and delays exhaust.

158. "Minus cover" or "minus lap" on the exhaust is the measured amount which the inside edge is open to the exhaust, with the valve standing in mid position. It decreases cushioning and hastens exhaust.

159. "Cushioning" or "compression" in a steam cylinder is caused by the communication of the cylinder with the condenser being closed before the end of the stroke, thus allowing the steam which remains in the cylinder to be compressed, and which thus acts as a cushion to the piston, and brings it gradually to a state of rest, by which means the heavy thud or knock which otherwise would occur is avoided. It is affected thus:—Should there be "cover" on the exhaust side, then cushioning would be increased; should there be minus "cover," then cushioning would be diminished.

160. "Mean effective pressure" is the average of all the variable pressures throughout the whole stroke. It is ascertained by measuring the average width of an indicator card.

161. A dial vacuum guage is an instrument which shows the difference between atmospheric pressure and any other pressure less than the pressure of the atmosphere. It consists of a thin elliptical metal tube, bent into a ring, and in communication with the condenser at one end, the other end being connected by a link to a toothed sector gearing with a small pinion, with a pointer attached, which indicates on a graduated index, and shows the amount of vacuum in the condenser. The principle of it is, the tube seeks to coil itself up by the atmospheric pressure acting on the outer surface, with a partial vacuum in the inside of the tube. It is used to indicate the amount of vacuum in the condenser. When the engines are working right, it should indicate from 25 to 28 inches of vacuum. The variations indicate an increase or decrease of back pressure on the piston.

162. The vacuum guage does not indicate the exact pressure there is in the condenser; you must have recourse also to the barometer. The actual amount of back pressure in the condenser is the difference between the barometer and the vacuum guage.

163. A barometer is an instrument for measuring the pressure of the atmosphere. It consists of a glass tube placed vertically, and about 32 inches long, filled with mercury, and hermetically sealed at one end, the other end being open to a cup of mercury, which is open to the atmosphere. The mercury in the glass tube falls until the column of mercury is balanced by the pressure of the atmosphere, thus shewing the least variations of atmospheric pressure. The difference between the barometer and vacuum guage barometer is, that the top end of the glass tube, instead of being closed, is open to the condenser, and is bent in the form of a syphon pipe. Should the vacuum be perfect the mercury would be forced up one leg of the pipe or tube, thus indicating the amount of vacuum. Should the guage not be working, the mercury would stand in equal heights in each leg of the tube.

164. Both guages are graduated from atmospheric pressure. The steam guage indicates the pressure above the atmosphere, and the vacuum guage indicates the pressure below the atmosphere. The readings of the steam guage must have the atmospheric pressure added to obtain the true actual pressure in the boiler. The vacuum guage gives the true actual pressure below the atmospheric pressure.

165. If the steam guage shows 60lbs per square inch, the vacuum guage 10lbs per square inch, and the barometer equals 15lbs per square inch, the difference of pressure between the condenser and boiler will be 70lbs per square inch.

Steam pressure	60lbs
Atmospheric pressure..	15
	75
The difference between vacuum guage and barometer ...	5
Difference between boiler and condenser pressure.........	70lbs

166. The meaning of the words "inches of vacuum" is derived from the use of mercurial guages; thus a column of mercury is balanced, for every two inches rise in the tube, by 1lb of atmospheric pressure; thus when we speak of 20 inches of vacuum, we have 10lbs pressure per square inch. The pressure of the vapour in the condenser is found by taking the difference of the barometer and vacuum guage. Thus, should the

Barometer indicate...15lbs
Vacuum guage.........10

Then 5lbs is equal to the pressure of the vapour in the condenser.

167. A pump will draw from about 26 feet. The theoretical limit is 34 feet, but the air above the water in the pump cannot be completely exhausted, so that water will rise little above 25 feet. The limit that water will rise in a pipe with a perfect vacuum above, and the barometer standing at 30 inches, is 34 feet high. The reason is that the atmospheric pressure will not balance a weight greater than its own pressure.

168. Vacuum is a space void of air, vapour, or water. Vacuum and atmospheric pressure can work an engine, but not vacuum alone. There cannot be a vacuum with water in a condenser at 212° F. The water would boil and give off vapour at that temperature.

169. A thermometer is an instrument for measuring heat. It consists of a glass tube and bulb, containing mercury or spirits. The tube is connected to a graduated scale, which indicates the height of the mercury in the tube. The property of mercury or spirits is that they expand by heat and contract by cold, thus indicating a high or low temperature. Marine engineers use it for purposes of testing the heat of water drawn from the boiler, to test its density by the salinometer. It is used for testing the heat of the engine-room; also for testing the feed water.

170. The temperature of melting ice is 32° F.; of boiling water, 212° F.; of steam at 60lbs. pressure, 294° F.; of superheated steam, 380° F.; of smoke in the funnel, 600° F.; and of water in the hotwell, 110° F.

171. By "conduction" of heat is meant heat passing from particle to particle of a solid body; thus, if a bar of iron be put into the fire, the heat will travel from one end to the other. In a boiler the heat passes from the outside of a plate to the inside, and in a cylinder from inside to outside by conduction of heat.

172. By "convection" of heat is meant, the conveyance of heat from one place to another; thus the water about the furnaces is heated, expand, and become lighter, causing it to rise to the surface, and giving place to the colder water, which, in its turn, descends and becomes heated; thus heat is conveyed from one place to another. Heat is conveyed by the passage of steam from the boiler to the engine.

173. By "radiation" of heat is meant, the spreading out of heat in straight lines in every direction. When the boiler is heated, it will give out its heat to surrounding bodies that are cooler than itself by radiation, and to prevent this the top of the boiler is covered with some non-conducting material, thus keeping the heat frem radiating. The cylinders and steam pipes are similarly covered.

174. Heat from the glowing fuel to the furnace crown is radiation and convection; heat passing from one side of the furnace crown plate to the other is conduction; heat passing from the steam pipes in the engine-room is radiation; heat of evaporation is convection.

175. The effective heating surfaces of a marine boiler are: The furnace crowns; combustion chamber plates; tube plates and tubes. An objection to vertical heating surfaces is, that the heat does not strike the vertical surfaces so effectually as it does the horizontal surfaces.

176. The parts of a marine engine exposed to danger when the temperature is below freezing point are: All close chambers, condensers, pipes, and all pumps.

177. The necessary precaution is to run all water out of chambers, condensers, pipes, and all pumps.

178. A boiler might not get its full feed through leaky boilers, leaky joints or pipes, leaky feed check valve, through the feed pump escape valve spring becoming eased back, thus allowing the discharge water to return to the suction valve again.

179. Furnace bars are generally made of cast iron, about one inch thick at the top, with about half inch space between them. The bars are put further apart for Welsh coal.

180. Newcastle coal burns faster; it is the flaming coal, and it makes the most smoke.

181. About 11½ tons of coal per day. For example, take the length of furnace to be 6ft., and allowing 15lbs of coals to be burnt per hour per square foot of grate surface.

$$\text{We have } \frac{\overset{\text{Furnaces.}}{4} \times \overset{\text{Width.}}{3} \times \overset{\text{Length.}}{6} \times \overset{\text{Hours.}}{24} \times \overset{\text{lbs.}}{15}}{2240\text{lbs. in a ton.}} = 11.5 \text{ tons.}$$

182. Taking $\frac{2}{3}$ beam for height, and $\frac{3}{4}$ of height for immersed section, then $\frac{\text{Beam}^2}{2}$ = area of immersed section; using formula given by Boulton and Watt

$$\text{I.H.P.} = \frac{S^3 A}{C}$$

When S = speed of vessel per hour,
„ A = area of immersed section,
„ C = co-efficient, which differs for different vessels;

but may be taken at 800 for those of ordinary type. Then allowing 3lbs per I.H.P. per hour, we get 32 tons per day.

183. About 15 tons per day would be required for an ordinary pair of surface-condensing engines. By allowing 28 circular inches to one N.H.P., and assuming that the I.H.P. is four times the N.H.P., and allowing 3lb per I.H.P., we have the following formula :—

$$\left\{\frac{2\text{ dia.}^2 \times \overset{\text{lbs.}}{3} \times \overset{\text{Hours.}}{24}}{28 \times 2240}\right\} 4\text{ N.H.P.} = 15\text{ tons.}$$

184. The difference caused by the loss of the liner under the circumstances named, will be that on the upstroke the admission of steam would be later, the cut-off earlier, and the exhaust would open earlier; on the downstroke the admission of steam would be early, the cut-off would be late, and the exhaust would be late.

185. In a right-handed propeller, with the engines going ahead, the pressure would be greatest on the port side bar, both in the upstroke and the downstroke.

186. A screw propeller getting slack on the shaft, and with a little side play on the feather key, would indicate itself by a noise and vibration in the engine room, more particularly in the starting or reversing of the engines.

187. I would disconnect the piston rod from the crank, place the crank on the top centre, with the piston rod drawn out as well, measure the distance from the piston rod to the crank cheek; now turn the crank on the bottom centre and push the piston rod down also, see if the distance is the same top and bottom; if not, then the centre line of trunnions are not in a line with the crankshaft.

188. By removing the coupling bolts, and observing whether the shaft falls out of line.

VERBAL QUESTIONS.

1. You find your guage glass full of water; what would you do ?

Ans. Open the blow through cock to blow the glass clear; if it rose again, then open the test cocks; should all give water, then blow the boiler down.

2. The H.P. slide valve breaks; what would you do ?

Ans. Remove the pieces, remake the joint, and work with the L.P. engine.

3. Would you retain the same boiler pressure, or would you reduce it ?

Ans. I would reduce it to 20lbs. or 25lbs. pressure per square inch.

4. What would you do if your L.P. slide valve breaks ?

Ans. Remove the pieces, remake the joint, and work with the H.P. engine.

5. Would you carry the same steam pressure as before ?

Ans. No; the L.P. steam chest would become part of the condenser, so that now you would have the original pressure + vacuum, which would throw too great a strain on the working parts, and possibly cause a breakdown. It would be advisable to reduce the pressure to the original pressure — vacuum.

6. Suppose your crank pins become heated at first starting, and continued the whole voyage; what would you suppose to be the cause of it, providing your brasses were good and clean ?

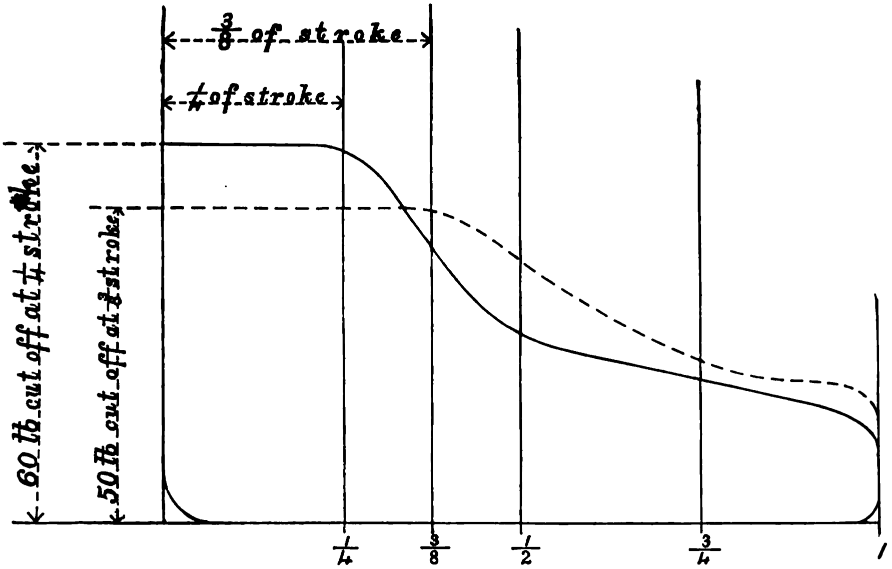
Ans. The crank pins would have too little bearing surface.

7. How would you remedy the above defect ?

Ans. I would make the cut off occur later, and reduce the steam pressure, which would give more equal pressure throughout the whole stroke.

8. Show the preceding statement by means of a diagram, and give

the pressure you would work at. The original pressure having been 60lbs., cut off ¼ stroke.



I would work at 50lbs. pressure, and make the cut off ⅜ of stroke, thus keeping the same mean pressure on the piston, and decreasing the pressure on the crank pin.

9. Your crank shaft on after engine breaks; what would you do?

Ans. If the crank shaft be in duplicate, take the fore part, and put it in the place of the after part.

10. How would you put the crank on the centres?

Ans. Place the crank a little off the centre, and by means of a trammel, which has one end in a centre dab on the column, draw a line across the end of the crank web, also mark the position of shoe on the guide; now turn the crank past the centre until the shoe comes down to the mark on the guide, make another mark with the trammel, find the centre of the two marks, and make a centre punch dab, turn the crank back until the trammel points in the dab, then the crank is on the centre.

11. You have two equal sized pipes from the bilge, one comes direct to the air pump, the other to the condenser; which pipe would draw the most water away from the bilge?

Ans. The one on the condenser, because of the constant vacuum.

12. Would you open the cock on the condenser full, or what would be your limit?

Ans. I would open it sufficiently to allow the air pump to keep the condenser from having too much water.

13. What are the evils arising from using this cock?

Ans. All dirt is forced up into the condenser and pump, thus gagging the valves, and supplying the boiler with impurities.

Note.—Bilge injections are fitted to the circulating pump on surface condensing engines.

14. What would you do supposing (A) the air pump broke down, (B) the circulating pump, (C) the feed pumps, (D) the bilge pumps?

Ans. (A) Take condenser end doors off, and draw a good number of tubes, remake the joint, open the jet injection valve, thus allowing the circulating pump to draw all the water and condensed steam away. I would also partly close the main injection valve; the boilers would have to be fed with salt water. (B) I would start the donkey for purposes of circulation. (C) I would start the donkey for feeding the boiler. (D) I would connect the donkey to the bilges and pump overboard.

15. Explain fully the steps you would take on a leak gaining upon the vessel?

Ans. Put both bilge pumps to work, start the donkey, open the bilge injection valve, and place a hand to look after the strums to prevent any dirt or chips from entering the pumps.

16. Supposing the bilge injection gets stopped up, what would you do?

Ans. I would try all means to clear it. If I could not get it clear, then I would cut some holes higher up the pipe, but as low as possible in the water, place a basket over the end to act as a strum, and place a man to keep it clear.

17. Supposing both connecting rods broken; what would you do?

Ans. Disconnect the shaft, thus allowing the propeller to revolve freely.

18. Supposing your go-ahead eccentric broke, what would you do?

Ans. Place the go-astern one in its place, and secure the end of the reversing link; also inform the officer in charge on deck that the engines would not reverse.

19. Supposing your H.P. slide valve spindle breaks, what would you do?

Ans. Remove all the valve motion gear, take the slide valve out and secure the stuffing box with a blank flange, and work her with the L.P. engine, but with less pressure.

20. If the safety valve is set fast, how would you relieve the pressure in the boiler?

Ans. Close the damper and check the fires, putting on all feed, and letting the steam pass through the engine.

21. How would you feed the boiler when the engines are not working?

Ans. By the donkey, or hand feed pump.

22. How many valves has a feed pump? Name them.

Ans. Three. Suction, discharge, and overflow valves.

23. How many valves has a bucket air pump? Name them.

Ans. Three. Foot, bucket, and head valve.

24. Supposing the lap and lead to be the same top and bottom, on which side of the piston would the steam be cut off earliest? Why?

Ans. On the bottom. It is owing to the obliquity of the connecting-rod.

25. Is it more or less equal in the case of a short or long connecting-rod?

Ans. It is more equal in the case of a long connecting-rod.

26. Is there more or less water in a cubic foot of high or low pressure steam?

Ans. There is more water in a cubic foot of high pressure steam.

27. How much steam at atmospheric pressure will one cubic inch of water make?

Ans. One cubic foot of steam.

28. How could you tell if the condenser tubes were leaking?

Ans. By the water rising in the boiler, or by tasting the feed water.

29. What would you do if the water in the boiler fell below the lowest test cock?

Ans. Draw the fires, ease the safety valves and work the steam off, open smoke box doors, examine tube ends and combustion chamber, pump the boiler up with water, see if any tubes leak, if so, plug them up, light fires, raise steam, and proceed.

30. You have two boilers, and the check valve of one of them is broken, what would you do to regulate the water in the boiler?

Ans. Allow the boiler with the broken valve to feed up what it would, taking care not to allow the salt water feed to be opened (unless required), closing the feed check valve on the other boiler, and allow the donkey to draw from the hot well, and pump through the donkey feed check valve into the boiler.

31. How do you change the water in the boiler ?

Ans. By feeding up and scumming or blowing off from the bottom.

32. Give the boiling point of fresh water, sea water, and the limit of the boiler water in the open air, and explain what effect the height of the barometer has upon them ?

Ans. Fresh water boils at 212°, sea water at 213·2°, boiler water should not exceed more than 214·4°, for every rise of ½ inch in the barometer ·8° ought to be added, and for every ½ inch fall ·8° ought to be subtracted.

33. Supposing you lost your salinometer, and you wished to test the density of your boiler water, what would you do ?

Ans. Draw some water off, boil it, and test its boiling point by the thermometer, also consulting the barometer.

34. You are in the engine-room, for some reason you have not noticed the steam guage, the steam has got up very rapidly, safety valves have set fast, what will you do to relieve the boiler of its pressure ?

Ans. Close all dampers, put all feed on, open the scum cock and blow off a little, and work it down by the engine.

35. If the blow off cocks are set fast, how would you change the water in the boiler ?

Ans. By using the scum cock.

36. You have three furnaces, and the coals are so bad that one of the fires has to be constantly out for cleaning, what would the consequence be ?

Ans. A great loss of steam ; it would be the means of causing the tube ends and other joints to leak.

37. How are the boilers kept supplied with water ?

Ans. By the feed pumps drawing water from the hot well, and forcing it into the boiler.

38. What are stuffing boxes ?

Ans. Recesses formed round piston rods, pump rams, &c., to contain packing, which is kept in position by a gland screwed up to keep them steam or water tight.

39. What are the uses of the slide valves ?

Ans. To allow the admission and exit of the steam on the top and bottom side of the piston.

40. How do you know when the engines are starting properly ?

Ans. By observing the vacuum guage rising steadily, by feeling the discharge pipe, and by noticing that all parts of the engine are working smoothly.

41. Supposing all the bolts of one coupling were broken, and you had no others to put in, what would you do?

Ans. I would take one bolt from each of the other couplings until I could get more.

42. What would you do before leaving the engine-room after arriving in port?

Ans. Draw all fires and ease the safety valves.

43. What would you do on coming on watch?

Ans. Look at the steam guage and glass water guage, test the water in the boiler by the salinometer, see that all the working parts are cool and well lubricated, examine the tunnel to see if all things are right, and see that the firing and stokehole is properly attended to.

44. You are on watch, and you find one boiler with the water falling in the glass, what would you do to get more water into the boiler.

Ans. Open the check valve full and ease down the other, also open the salt-water feed cock a little.

45. Name the cocks and valves that open into the sea?

Ans. Main injection, main discharge, donkey suction, donkey discharge, blow off, ash cooling, and water service cocks.

46. Explain the use of the cylinder, and name the different valves and cocks fitted to it?

Ans. The use of the cylinder is to receive the steam from the boiler, and the steam by its elastic force on the surface of the piston gives motion to the engine. The valves and cocks are:—Slide valves, expansion valves, throttle valves, escape valves, drain cocks, and grease cups.

47. What is the use of the throttle valve?

Ans. To regulate the flow of steam to the steam chest.

48. What is the use of the stop valve?

Ans. To close or open communication between the engine and boiler, or between two boilers.

49. What is the reverse or atmospheric valve?

Ans. It is a valve fitted to a boiler of low pressure; it opens inwardly; it prevents a vacuum from forming in the inside of a boiler.

50. What is the hotwell?

Ans. It is a large tank or chamber to receive the condensed steam pumped up from the condenser by the air pump. Should it become too full a discharge valve is fitted to the ship's side to allow the surplus water to be discharged overboard.

51. How would you increase the mean pressure in the cylinder ?

Ans. By taking some of the lap off and readjusting the eccentric.

52. Supposing you had a faulty crankshaft, and the fault lay in the second bearing on the fore engine, what would you do ?

Ans. I would put more lap on the slide valve, and advance the eccentric sheave so as to have the greatest strain upon the after engine.

53. What means would you use to ascertain whether the outer end of a paddle shaft was down ?

Ans. I would disconnect the cranks, and turn the cranks on the top centre, and measure the distance between the two faces close to the crank pin, then turn the cranks on the bottom centre, and measure the distance between the two faces at the same points. If they were equal, then the end of the shaft would be in a line with the intermediate shaft; if they were further apart at the top, then the outer end would be down.

54. What means would you use so as to ascertain whether the outer shaft was out of centre line with the intermediate one ?

Ans. I would disconnect the two cranks, place them on the top centre, find the centre of the outer shaft, make a guage reaching from the centre to close up to the crank pin on the opposite crank, and make a mark, turn the cranks on the bottom centre, see if the guage will reach the mark, if so, then the shafts are in a line; suppose the guage reaches beyond the mark then the centre of the outershaft is below the centre of the intermediate shaft.

55. To what is the auxiliary feed connected ?

Ans. It is connected at one end to the circulating discharge water, and leading into the hotwell or condenser.

56. What is its use ?

Ans. To allow a little salt water to mix with the feed water to supply what has been lost by leakage through stuffing boxes, &c.

57. What is the use of the hotwell discharge valve ?

Ans. It is used in case the engines are to be worked common jet, or in case of too much water accumulating in the hotwell.

58. How would you increase the temperature of your feed water ?

Ans. By using less circulating water.

59. What would be the disadvantage should the temperature get too high ?

Ans. There would be a bad vaccuum, and the air pump valves would be destroyed.

60. Suppose an engineer by an act of carelessness closed the feed check valve close down, what would happen ?

Ans. The feed pump overflow valve would come into operation, thus preventing the pipes from bursting.

61. If the bridle links were broken, what would you do?

Ans. I would attach pairs of rope blocks to each end of the reversing link, the other end of the blocks attached to eye-bolts secured to the bunker or ship's side.

62. If the bottom half of the go-ahead eccentric strap were to break what would you do?

Ans. Take the go-astern half strap and fix it in the place of the broken half, and hang some heavy weight on the end of the reversing link to keep the go-astern half strap on the sheaf; of course she would not reverse.

63. Suppose the go-ahead sheave were to break, what would you do?

Ans. Remove the broken sheave, and fix the go-astern one in its place, and secure the end of the link; in this case also the engine could not be reversed.

64. If your bottom end bolts were to break, what might be the result?

Ans. The cylinder cover and piston might be smashed, or the cylinder bottom knocked out; cast iron columns and cylinders have been cracked or broken by such a break.

65. How much lead would you give the H.P. engine and the L.P. engine?

Ans. The H.P. engine ought to have $\frac{1}{32}$ on the top, and $\frac{5}{16}$ on the bottom; the L.P. engine on the top $\frac{1}{8}$, and on the bottom $\frac{7}{16}$.

66. How would you set valves?

Ans. By putting the engine on the top and bottom centres, and placing the sheave so that its centre would be the amount of lap and lead added together, below the centre line of shaft with the engine on the top centre, and above the centre line of shaft with the engine on the bottom centre?

67. About what part of the stroke would you make her cut off at?

Ans. About $\frac{1}{2}$ or $\frac{5}{8}$ of the stroke.

68. How is it done?

Ans. By putting more or less lap on the slide valve.

69. How can you make the engine cut off earlier with the same amount of lap, and without altering the sheave?

Ans. By "linking up."

70. Can you gain a very early cut-off by this means?

Ans. No.

71. What effect would this have on the lead of the slide valve?

Ans. It would increase the lead.

72. Which is the most approved way of gaining expansion?

Ans. By using a separate expansion valve.

73. Is it generally adopted on compound engines?

Ans. No.

74. Why?

Ans. Because the principle of the compound engine itself is the principle of expansion carried out to its fullest extent.

75. Explain how this occurs?

Ans. The steam enters the H.P. cylinder at a high pressure; it is cut off at half stroke, and allowed to expand the rest of the stroke; it exhausts into the low pressure steam chest and enters the L.P. cylinder, where it is again cut off at half stroke, and allowed to expand again, thus obtaining the best expansion and most useful work out of a small quantity of steam at a high pressure.

76. Which class of engine are expansion valves mostly used on?

Ans. On ordinary surface condensing engines.

77. About what pressure do they generally work at?

Ans. About 40lbs. per sq. in.

78. About what part of the stroke do they generally cut off at?

Ans. About $\frac{1}{8}$ of the stroke.

79. Which is the most economical engine, the compound or the ordinary engine?

Ans. The compound engine.

80. What is the relative proportion per lb. of coal burnt per I.H.P. for each engine?

Ans. The compound engine burns about 1¾lbs. to 2lbs., whereas the ordinary engine burns from 3lbs. to 4lbs. of coal per I.H.P.

81. What is friction?

Ans. Friction is the resistance offered to one body when rubbed upon another body.

82. Does friction increase with the extent of rubbing surface?

Ans. No, so long as there is no heating, the friction is simply due to the pressure applied, so that a bearing may be as long again, and the friction not increased, but the durability of the bearing will be increased considerably.

83. Does friction increase with the velocity?

Ans. Yes, if compared with the time during which friction acts, thus if the engine makes 30 rev. per minute, there is a certain amount of friction generated; but if the revolutions are increased to 60 per minute, then the friction is increased twice, viz., for every stroke of the engine there is a certain amount.

84. What is meant by vacuum?

Ans. An empty space, in which there is neither water nor air.

85. Is there a perfect vacuum in the condenser?

Ans. No, because the condensed steam always emits a vapour, thus causing a slight pressure.

86. What instrument indicates the amount of vacuum in the condenser?

Ans. The vacuum guage.

87. Upon what does the forming of a vacuum depend?

Ans. Upon the efficient working of the air pump.

88. What are the different kinds of steam used?

Ans. Superheated, combined, and saturated steam.

89. What is meant by superheated steam?

Ans. The steam, after leaving the steam space in the boiler, passes through a tube or pipe into a chamber called the superheater, which is generally situated at the base of the funnel in the uptake, so that it is always surrounded with the heated gases, which would otherwise be wasted, thus increasing the sensible heat to a higher degree than the boiling point of water by no increase of consumption of fuel.

90. What objection is there to using superheated steam?

Ans. It destroys all packing in stuffing boxes very rapidly; the cylinders and valve faces require a great amount of lubrication; it acts very injuriously upon the surface of the cylinder and valve faces, causing them to cut in some cases.

91. What is meant by combined steam?

Ans. It is the amalgamation of superheated steam and steam direct from the boiler.

92. What is meant by saturated steam?

Ans. The steam which comes direct from the boiler without having its temperature increased more than what is due to boiling water.

93. Which is the most beneficial in all respects?

Ans. The combined steam.

94. What is the rule for finding the N.H.P. of a modern compound engine?

$$\frac{D^2 + d^2}{32} = \text{N.H.P.}$$

When D^2 diam. of large cylinder in inches.
,, d^2 ,, small ,, ,,
,, 32 is constant or varies with different engine builders.

95. About how many times the N.H.P. does an engine work actually up to generally?

Ans. About six times.

96. What is the formula for working out the I.H.P. from an indicator card?

$$\frac{a \times m \times 2s \times r}{33{,}000} = \text{I.H.P.}$$

When a area of cylinder.
,, m mean pressure on the piston.
,, s stroke of engine.
,, r revolutions per minute.

97. Give the relative strengths of cast iron and wrought iron in tensile and compressive strains?

Ans. Wrought iron will stand twice the strain cast iron will in tension. Cast iron will stand twice the strain wrought iron will stand in compression.

98. Which is the best arrangement of engine for paddle boats?

Ans. The oscillating.

99. Why is this kind of engine preferred?

Ans. On account of the little space occupied; it consists of few parts, the piston rod being connected direct to the crank, thus dispensing with a connecting rod.

100. How is steam admitted and released from an oscillating engine?

Ans. It is generally admitted by the two outside trunnions for the sake of convenience, so as to reserve the two inside trunnions for the release or exhaust steam, which are nearest the condenser.

BOILER.

1. Trace the combustion of coal ?

Ans. The coal is thrown upon the firebars, the smoke and gases pass over the bridge into the combustion chamber, through the tubes into the smoke-box, through the uptake, and then up the funnel.

2. What is coal composed of ?

Ans. Carbon, hydrogen, nitrogen, sulphur, oxygen, and ash.

Locality.	Carbon.	Hydrogen.	Nitrogen	Sulphur.	Oxygen.	Ash.
Welsh	83½	4¾	1	1½	4¼	5
Newcastle	82¼	5½	1½	1¼	5¾	3¾

3. Name all doors about a boiler ?

Ans. Fire doors, smoke-box doors, ash pit doors, manhole doors, and sludge doors.

4. Name all pipes about a boiler ?

Ans. Funnel, main steam pipe, donkey steam pipe, waste steam pipe, blow off and scum pipe, feed pipes, pipes connecting water guages and drain pipes for test cocks and water guages.

5. Name all the cocks and valves about a boiler ?

Ans. Safety valve, main steam stop valve, feed check valves, reverse valves, blow off, scum, whistle, test, water guage, and salinometer cocks.

6. Name all the internal parts of a boiler ?

Ans. Furnaces, combustion chamber, tubes, tube plates, and stays.

7. What is steam space ?

Ans. The space in a boiler above the water.

8. What are tubes used for in a boiler ?

Ans. To afford more heating surface to the water by which they are surrounded, thereby creating steam more rapidly, and also saving much useless weight of water being carried.

9. How high should the water stand above the tubes ?

Ans. About 6 inches.

10. How would you detect a thin plate in a boiler?

Ans. By tapping with a hammer, or drilling a hole through and plugging it again.

11. What would you do if you found the plates wasted very much?

Ans. Reduce the pressure?

12. Suppose you have six boilers, and after being underweigh you found five of them are getting feed water, but the sixth is not feeding at all, what would you suppose to be the cause of it?

Ans. An excess of pressure in the sixth boiler.

13. What form of boiler is strongest?

Ans. Spherical, then cylindrical.

14. What fixes the pressure to be allowed on a circular boiler?

Ans. The diameter and thickness of plates.

15. What is the formula for the pressure?

$$P \quad \frac{s \times 2t}{d}$$

When P pressure to be allowed.
,, s strain per sq. in. on plate.
,, t thickness of plate.
,, d diameter of boiler in inches.

16. Does a spherical boiler require stays?

Ans. No.

17. Why?

Ans. Because the pressure acts on the shell in all directions.

18. What parts of a circular boiler require staying?

Ans. The ends and all flat surfaces, such as combustion chamber backs and sides.

19. Why are large wrought iron girders placed across combustion chamber tops?

Ans. To prevent them from collapsing.

20. How would you strengthen a furnace tube?

Ans. By riveting a piece T iron on the outer surface.

21. How would you fix it?

Ans. I would encircle it round the tube, and insert short distance pieces to keep it from the tube, and rivet them all together, thus allowing the T iron to stand off the plate to allow the water to come in contact with the tubes as before; by this means the plate would not be liable to brun or become unduly heated.

22. Which would be strongest, a lap joint or a butt strap joint of a furnace tube ?

Ans. The butt strap joint.

23. Why ?

Ans. Because it would form a true section of a circle.

24. What is the limit of strength of a tube ?

Ans. Its diameter, thickness, and length.

25. What is the rule for the collapsing strain of furnace tubes ?

Ans. $$\frac{89000 \times T^2}{L \times D} = \text{pressure to be allowed per square inch.}$$

Where 89000 = constant

T = thickness of plate in inches.

D = outside diameter of furnace in inches.

L = length of furnace in feet.

26. Why are compensating rings rivetted round manholes ?

Ans. To make up the loss of strength of plate, by cutting the manhole.

27. Why is a shield plate fixed on the front of the boiler in the uptake ?

Ans. To preserve the ends of the stays and nuts, also to keep the heated gases from the plate.

28. Suppose your furnace crown came down ; what would you do ?

Ans. I would put girders and stay bolts on the top to prevent its further collapse.

29. If one of the screwed stays were corroded away, and the plate too thin to be retapped, what would you do ?

Ans. Drill it out, and put one in with double nuts and large washers.

30. You found a crack in a boiler plate ?

Ans. Drill a hole, tap and plug it, drill another partly entering the other plug, plug it, and so on the length of the crack.

31. One of the boiler tubes were to burst ?

Ans. Blow off all steam and draw fires, chip the ends of the tube flush, and insert a long stay bolt with nuts and washers at the ends, thus making a joint at each end and effectually stopping all leakage, light fires again and proceed.

32. What would happen if there is not sufficient water in the boiler ?

Ans. The combustion chamber, or the top row of tubes would collapse.

33. If there is too much water in the boiler what will be the consequence?

Ans. Priming will take place, and may cause a break down of the engine.

34. What are wash plates which are secured about the water level in the boiler for?

Ans. To prevent the rush of water from one side of the boiler to the other, when the vessel is rolling deep.

35. What is meant by banking up the fires?

Ans. The burning fuel is pushed back against the bridge, and small wet coals and ashes thrown on them to retard the formation of steam, thus keeping the fire handy and ready for action at a moment's notice.

36. How many safety valves are generally fitted to one boiler?

Ans. Two, in case one should stick the other will be free to move, it is also done so that one may be a lock-up valve to prevent any additional pressure being put on, the other is accessible by the engineer, in case he wishes to reduce the pressure at any time.

37. What is the use of the safety valves?

Ans. To allow the steam to escape when it has reached its proper working load.

38. How much heating surface is allowed per N.H.P.?

Ans. About 21 square feet.

39. How much grate surface?

Ans. About $\frac{5}{3}$ square feet.

40. How much steam space?

Ans. About 5 cubic feet.

41. How much water will a pound of coal evaporate?

Ans. About 10 lbs. water.

42. How much air is required for the combustion of 100 lbs. of coal?

Ans. 15000 cubic feet of air.

43. What is meant by the combustion of coal?

Ans. The combination of the oxygen of the atmospheric air, with the carbon and the hydrogen of the coal.

44. How does this take place?

Ans. By heat.

ON WORK.

A steam engine is said to do *work* when it is used to move any kind of machinery.

UNITS OF WORK.

One unit of work is the force necessary to raise vertically one pound weight through the space of one foot, and it is called a *foot-pound.*

Another unit of work is the force necessary to raise vertically one ton weight through the space of one foot, and it is called a *foot-ton.*

If a man raise a pound weight one foot high, he will perform one unit of work, if he raise it two feet he will perform two units of work, if he raise it three feet he will perform three units of work; and so on.

Again, if he raise two pounds one foot high he will perform two units of work, if he raise three pounds one foot high he will perform three units of work; and so on.

Again, if he raise three pounds two feet, he will perform six units of work; for in raising the three pounds the first foot he performs three units of work, and in raising them the second foot he also performs three units of work.

Now $6 = 3\times 2$

Thus, in this instance, the number of units of work is obtained by multiplying the number denoting the pounds weight by the number denoting the feet through which the weight is raised vertically.

A similar result follows in every case; hence we have the following

RULE.

The product of the weight of the body in pounds into the vertical height in feet through which it is raised is the measure of the work performed in raising it

Watt estimated that a horse could raise vertically 33,000 pounds weight one foot high in one minute of time, and he took this as another unit of work, and called it a *Horse Power*.

WORK DONE BY PUMPS.

In figure 16, let E B D F, represent the volume of water lifted by every stroke of the pump, and A B the length of the stroke in inches, then, the pump being a cylinder, we have, by Article 10, for the volume of a cylinder in cubic inches the formula:

$$v' = \cdot 7854\, d^{2}\, h \ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\text{Let} \quad \left.\begin{array}{lll} s & = & \text{length of stroke} \\ f & = & \text{fraction that the pump is full} \end{array}\right\} \text{in inches}$$

Then $s\,f = h$, **in formula 1.**

Hence by substituting this value we have the formula

$$v'' = \cdot 7854\, d^{2}\, s\, f \ldots\ldots\ldots\ldots\ldots\ldots 2$$

For the volume of water lifted by every stroke of the pump.

Let n = **number of strokes in a minute.**

then $60n$ = „ „ **an hour.**

Hence, by multiplying formula 2 by 60 n **we have the formula**

$$v''' = \cdot 7854\, d^{2}\, s\, f\; 60\, n \ldots\ldots\ldots\ldots\ldots\ldots 3$$

For the volume of water, in cubic inches, pumped out in an hour.

Next, divide formula 3 by 1728, the number of cubic inches in a cubic foot, and we obtain the formula.

$$v = \frac{\cdot 7854\, d^{2}\, s\, n\, 60 f}{1728} \ldots\ldots\ldots\ldots\ldots\ldots \text{A}$$

For the volume of water, in cubic feet, pumped out in an hour by a single acting pump. Formula A must be multiplied by 2 when the pump is double acting.

WORK DONE BY THE STEAM ENGINE.

By Article 7, Formula A, the expression for the area of the circle is:

$$a = \cdot 7854\, d^{2} \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Let p = pressure, in pounds, on every square inch of the piston; then, by multiplying both sides of equation 1, by p we have

$$a\, p = \cdot 7854\, d^{2}\, p \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Which is the expression for the whole of the pressure on the piston; now every revolution of the crank causes one stroke of the piston up, and another down, that is, it causes two strokes, let r = number of revolutions of the crank per minute, let s = length of the stroke in feet, then $s \times 2\, r$ is the expression for the distance in feet, moved by the piston per minute; and by multiplying the pounds weight moved, by the distance in feet, through which it is moved per minute, and putting u for the units of work done, we have

$$u = \cdot 7854\, d^2\, p\, s \times 2\, r \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Which is the expression for the units of work done by the engine in 1 minute?

Divide equation 3 by 33000, and put $H.P.$ for the horse power, and we obtain the formula

$$H.P. = \frac{\cdot 7854\, d^2\, p\, s \times 2 r}{33000} \ldots\ldots\ldots\ldots\ldots\ldots\ldots A$$

FORMULÆ FOR THE WORK OF A STEAM ENGINE.

Let $H.P.$ = horse power.

s = length of stroke; in feet.

a = numerator of fraction of cut off.

b = denominator ,,

$\frac{a\, s}{b}$ = distance of cut off; in feet.

P = pressure that steam is admitted into the cylinder } in lbs

p = mean pressure of the steam } in lbs

d = diameter of cylinder; in inches.

r = revolutions per minute.

n = $2\, r$ = number of strokes per minute,

u = units of work done on each square inch of the piston during a single stroke.

Then we have the following formulæ:

$$u = \frac{P\, a\, s}{b}\left(1 + \log \frac{b}{a}\right) = \frac{P s}{b}(1 + \log b), \text{ when } a = 1 \ldots A$$

$$p = \frac{P a}{b}\left(1 + \log \frac{b}{a}\right) = \frac{P}{b}(1 + \log b), \text{ when } a = 1 \ldots B$$

$$H.P. = \frac{\cdot 7854\, d^2\, p\, s\, n}{33000} \ldots\ldots\ldots\ldots\ldots\ldots\ldots C$$

Example 1. The steam is admitted into the cylinder at 45 lbs. per square inch above the atmosphere, and it is cut off at $\frac{1}{6}$th of the stroke, the length of the stroke is 12 feet, the diameter of the cylinder is 50 inches, and the piston makes 20 strokes per minute; required the mean pressure of the steam, the mechanical efficiency, and the horse power?

by formula B. $$p = \frac{P}{b}(1+\log b) = \frac{60}{6}(1+\log 6)$$

	lbs.	
Guage	45	= log. 6 = 1·7918. See the table of logarithms.
Atmos.	15	
Gross	60	

Therefore $$p = \frac{60}{6}(2{\cdot}7918) = 10 \times 2{\cdot}7918 = 27{\cdot}918 \text{ Ans.}$$

By formula C. $$H.P. = \frac{{\cdot}7854\, d^2\, p\, s\, n}{33000}$$

Therefore $$H.P. = \frac{{\cdot}7854 \times 50 \times 50 \times 27{\cdot}918 \times 12 \times 20}{33000}$$

By cancelling $$= {\cdot}0714 \times 5 \times 5 \times 27{\cdot}918 \times 4 \times 2$$

$$= 398{\cdot}66904 \text{ Answer.}$$

Note. If 1 represent the mechanical efficiency without expansion, then $(1+\log b) = 2{\cdot}7918$ represents the mechanical efficiency with expansion.

TABLE OF HYPERBOLIC LOGARITHMS TO FOUR PLACES.

N.	Logarithm.	N.	Logarithm.	N.	Logarithm.
1·01	·0100	1·39	·3293	1·77	·5710
1·02	·0198	1·40	·3365	1·78	·5766
1·03	·0296	1·41	·3436	1·79	·5822
1·04	·0392	1·42	·3507	1·80	·5878
1·05	·0488	1·43	·3577	1·81	·5933
1·06	·0583	1·44	·3646	1·82	·5988
1·07	·0679	1·45	·3716	1·83	·6043
1·08	·0770	1·46	·3784	1·84	·6098
1·09	·0862	1·47	·3853	1·85	·6152
1·10	·0953	1·48	·3920	1·86	·6206
1·11	·1044	1·49	·3988	1·87	·6259
1·12	·1133	1·50	·4055	1·88	·6313
1·13	·1222	1·51	·4121	1·89	·6366
1·14	·1310	1·52	·4187	1·90	·6419
1·15	·1398	1·53	·4253	1·91	·6471
1·16	·1484	1·54	·4318	1·92	·6523
1·17	·1570	1·55	·4383	1·93	·6575
1·18	·1655	1·56	·4447	1·94	·6627
1·19	·1740	1·57	·4511	1·95	·6678
1·20	·1823	1·58	·4574	1·96	·6729
1·21	·1906	1·59	·4637	1·97	·6780
1·22	·1989	1·60	·4700	1·98	·6831
1·23	·2070	1·61	·4762	1·99	·6881
1·24	·2151	1·62	·4824	2·00	·6931
1·25	·2231	1·63	·4886	2·01	·6981
1·26	·2311	1·64	·4947	2·02	·7031
1·27	·2390	1·65	·5008	2·03	·7080
1·28	·2469	1·66	·5068	2·04	·7129
1·29	·2546	1·67	·5128	2·05	·7178
1·30	·2624	1·68	·5188	2·06	·7227
1·31	·2700	1·69	·5247	2·07	·7275
1·32	·2776	1·70	·5306	2·08	·7324
1·33	·2852	1·71	·5365	2·09	·7372
1·34	·2927	1·72	·5423	2·10	·7419
1·35	·3001	1·73	·5481	2·11	·7467
1·36	·3075	1·74	·5539	2·12	·7514
1·37	·3148	1·75	·5596	2·13	·7561
1·38	·3221	1·76	·5653	2·14	·7608

TABLE OF HYPERBOLIC LOGARITHMS TO FOUR PLACES.

N.	Logarithm.	N.	Logarithm.	N.	Logarithm.
2·15	·7655	2·53	·9282	2·91	1·0682
2·16	·7701	2·54	·9322	2·92	1·0716
2·17	·7747	2·55	·9361	2·93	1·0750
2·18	·7793	2·56	·9400	2·94	1·0784
2·19	·7839	2·57	·9439	2·95	1·0818
2·20	·7885	2·58	·9478	2·96	1·0852
2·21	·7930	2·59	·9517	2·97	1·0886
2·22	·7975	2·60	·9555	2·98	1·0919
2·23	·8020	2·61	·9594	2·99	1·0953
2·24	·8065	2·62	·9632	3·00	1·0986
2·25	·8109	2·63	·9670	3·01	1·1019
2·26	·8154	2·64	·9708	3·02	1·1053
2·27	·8198	2·65	·9745	3·03	1·1086
2·28	·8242	2·66	·9783	3·04	1·1119
2·29	·8286	2·67	·9821	3·05	1·1151
2·30	·8330	2·68	·9858	3·06	1·1184
2·31	·8372	2·69	·9895	3·07	1·1217
2·32	·8416	2·70	·9933	3·08	1·1249
2·33	·8459	2·71	·9969	3·09	1·1282
2·34	·8502	2·72	1·0006	3·10	1·1314
2·35	·8544	2·73	1·0043	3·11	1·1346
2·36	·8587	2·74	1·0080	3·12	1·1378
2·37	·8629	2·75	1·0116	3·13	1·1410
2·38	·8671	2·76	1·0152	3·14	1·1442
2·39	·8713	2·77	1·0188	3·15	1·1474
2·40	·8755	2·78	1·0225	3·16	1·1506
2·41	·8796	2·79	1·0260	3·17	1·1537
2·42	·8838	2·80	1·0296	3·18	1·1569
2·43	·8879	2·81	1·0332	3·19	1·1600
2·44	·8920	2·82	1·0367	3·20	1·1632
2·45	·8961	2·83	1·0403	3·21	1·1663
2·46	·9002	2·84	1·0438	3·22	1·1694
2·47	·9042	2·85	1·0473	3·23	1·1725
2·48	·9083	2·86	1·0508	3·24	1·1756
2·49	·9123	2·87	1·0543	3·25	1·1787
2·50	·9163	2·88	1·0578	3·26	1·1817
2·51	·9203	2·89	1·0613	3·27	1·1848
2·52	·9243	2·90	1·0647	3·28	1·1878

136. Surface condensers foul from grease and oil on the steam side of the tubes, and should the condenser be worked at a high temperature, a deposit of saline matter will occur on the inside of the tubes. They are often cleaned by injecting soda into the condenser, and also, when in port, by taking the condenser end doors off, and inserting a small scraper into the tube and scraping all sediment off; or it may be done by scalding with hot water.

137. The non-conducting substances generally employed are felt, or a cement specially prepared. They are secured with wood or canvas. The surfaces are generally painted, and while the paint is wet the felt is applied to make it adhere; the cement is generally applied about three inches thick, and secured by wood.

138. Provision is made to lessen radiation by smoke-box doors and dry uptakes by means of air casing, standing about 2" from them, which allows the cold air to circulate freely round them.

139. The formation of black smoke can be prevented bv careful stoking, and by admitting a small quantity of air into the combustion chamber. Smoke-preventing apparatus all aim at giving a further supply of air to the furnaces.

140. By circulation in a boiler is meant, the water nearest to the heating surfaces expands and becomes lighter, thus rising to the surface and giving place to the colder water, which, in its turn, becomes heated and expanded, and rises to the surface; thus a constant circulation of water is going on in the boiler. The results of defective circulation are:—Priming, salting, and damaged plates.

141. The means sometimes adopted to improve circulation is by having circulating pipes in some parts of the boiler, which will allow the water to descend freely.

142. The circulation is promoted in haystack boilers by putting cross tubes in the flame box.

143. A ship's side air-pump discharge valve is a cast iron chest, with brass valve and seat fitted, a spindle being attached to the valve, working up through a stuffing-box and gland in the cover; it is weighted so as to keep shut of its own accord. It differs from a common valve inasmuch as it is self-acting, and does not screw up or down, but can be kept up or down by means of a cotter passing through the spindle. The attention it requires is to see that it is perfectly water-tight, otherwise water from the sea would find its way into the hotwell.

144. A feed escape valve is a cast iron chest fitted with a brass valve and seat, having a spindle working up through a stuffing box and gland in the cover. On each side of the spindle is a pillar, the pillars are connected at the top by a plate; the adjusting screw passes through the centre of the plate, the spring is fixed between this screw and the spindle. The discharge is in connection with the hotwell or suction pipes. The loading of the spring is regulated by means of the adjusting screw.

TABLE OF HYPERBOLIC LOGARITHMS TO FOUR PLACES.

N.	Logarithm.	N.	Logarithm.	N.	Logarithm.
4·43	1·4884	4·81	1·5707	5·19	1·6467
4·44	1·4907	4·82	1·5728	5·20	1·6487
4·45	1·4929	4·83	1·5748	5·21	1·6506
4·46	1·4951	4·84	1·5769	5·22	1·6525
4·47	1·4974	4·85	1·5790	5·23	1·6544
4·48	1·4996	4·86	1·5810	5·24	1·6563
4·49	1·5019	4·87	1·5831	5·25	1·6582
4·50	1·5041	4·88	1·5851	5·26	1·6601
4·51	1·5063	4·89	1·5872	5·27	1·6620
4·52	1·5085	4·90	1·5892	5·28	1·6639
4·53	1·5107	4·91	1·5913	5·29	1·6658
4·54	1·5129	4·92	1·5933	5·30	1·6677
4·55	1·5151	4·93	1·5953	5·31	1·6706
4·56	1·5173	4·94	1·5974	5·32	1·6715
4·57	1·5195	4·95	1·5994	5.33	1·6733
4·58	1·5217	4·96	1·6014	5·34	1·6752
4·59	1·5239	4·97	1·6034	5·35	1·6771
4·60	1·5261	4·98	1·6054	5·36	1·6790
4·61	1·5282	4·99	1·6074	5·37	1·6808
4·62	1·5304	5·00	1·6094	5·38	1·6827
4·63	1·5326	5·01	1·6114	5·39	1·6845
4·64	1·5347	5·02	1·6134	5·40	1·6864
4·65	1·5369	5·03	1·6154	5·41	1·6882
4·66	1·5390	5·04	1·6174	5·42	1·6901
4·67	1·5412	5·05	1·6194	5·43	1·6919
4·68	1·5433	5·06	1·6214	5·44	1·6938
4·69	1·5454	5·07	1·6233	5·45	1·6956
4·70	1·5476	5·08	1·6253	5·46	1·6974
4·71	1·5497	5·09	1·6273	5·47	1·6993
4·72	1·5518	5·10	1·6292	5·48	1·7011
4·73	1·5539	5·11	1·6312	5·49	1·7029
4·74	1·5560	5·12	1·6332	5·50	1·7047
4·75	1·5581	5·13	1·6351	5·51	1·7066
4·76	1·5602	5·14	1·6371	5·52	1·7084
4·77	1·5623	5·15	1·6390	5·53	1·7102
4·78	1·5644	5·16	1·6409	5·54	1·7120
4·79	1·5665	5·17	1·6429	5·55	1·7138
4·80	1·5686	5·18	1·6448	5·56	1·7156

serve uniformity of action, so that the piston may come to a state of rest gradually, and also that the engine may commence its stroke with pressure about $\frac{1}{16}$" on the top and $\frac{1}{4}$" or $\frac{3}{8}$" on the bottom.

156. The "cover" or "lap" of the slide valve is the measured amount which the outer edge of the valve overlaps the steam port, with the valve standing in mid position. Its object is to cut off the steam from the cylinder at a given part of the stroke, thus allowing the remaining part of the stroke to be accomplished by expansion of the steam. A good proportion is about $\frac{1}{3}$ of the stroke of the valve, but it all depends upon the cut off required.

157. "Exhaust cover" or "exhaust lap" of a slide valve is the measured amount which the inside edge of the valve overlaps the steam port with, the valve standing in mid position. It increases cushioning and delays exhaust.

158. "Minus cover" or "minus lap" on the exhaust is the measured amount which the inside edge is open to the exhaust, with the valve standing in mid position. It decreases cushioning and hastens exhaust.

159. "Cushioning" or "compression" in a steam cylinder is caused by the communication of the cylinder with the condenser being closed before the end of the stroke, thus allowing the steam which remains in the cylinder to be compressed, and which thus acts as a cushion to the piston, and brings it gradually to a state of rest, by which means the heavy thud or knock which otherwise would occur is avoided. It is affected thus:—Should there be "cover" on the exhaust side, then cushioning would be increased; should there be minus "cover," then cushioning would be diminished.

160. "Mean effective pressure" is the average of all the variable pressures throughout the whole stroke. It is ascertained by measuring the average width of an indicator card.

161. A dial vacuum guage is an instrument which shows the difference between atmospheric pressure and any other pressure less than the pressure of the atmosphere. It consists of a thin elliptical metal tube, bent into a ring, and in communication with the condenser at one end, the other end being connected by a link to a toothed sector gearing with a small pinion, with a pointer attached, which indicates on a graduated index, and shows the amount of vacuum in the condenser. The principle of it is, the tube seeks to coil itself up by the atmospheric pressure acting on the outer surface, with a partial vacuum in the inside of the tube. It is used to indicate the amount of vacuum in the condenser. When the engines are working right, it should indicate from 25 to 28 inches of vacuum. The variations indicate an increase or decrease of back pressure on the piston.

TABLE OF HYPERBOLIC LOGARITHMS TO FOUR PLACES.

N.	Logarithm.	N.	Logarithm.	N.	Logarithm.
6·71	1·9036	7·09	1·9587	7·47	2·0109
6·72	1·9051	7·10	1·9601	7·48	2·0122
6·73	1·9066	7·11	1·9615	7·49	2·0136
6·74	1·9081	7·12	1·9629	7·50	2·0149
6·75	1·9095	7·13	1·9643	7·51	2·0162
6·76	1·9110	7·14	1·9657	7·52	2·0176
6·77	1·9125	7·15	1·9671	7·53	2·0189
6·78	1·9140	7·16	1·9685	7·54	2·0202
6·79	1·9155	7·17	1·9699	7·55	2·0215
6·80	1·9169	7·18	1·9713	7·56	2·0229
6·81	1·9184	7·19	1·9727	7·57	2·0242
6·82	1·9199	7·20	1·9741	7·58	2·0255
6·83	1·9213	7·21	1·9755	7·59	2·0268
6·84	1·9228	7·22	1·9769	7·60	2·0281
6·85	1·9242	7·23	1·9782	7·61	2·0295
6·86	1·9257	7·24	1·9796	7·62	2·0308
6·87	1·9272	7·25	1·9810	7·63	2·0321
6·88	1·9286	7·26	1·9824	7·64	2·0334
6·89	1·9301	7·27	1·9838	7·65	2·0347
6·90	1·9315	7·28	1·9851	7·66	2·0360
6·91	1·9330	7·29	1·9865	7·67	2·0373
6·92	1·9344	7·30	1·9879	7·68	2·0386
6·93	1·9359	7·31	1·9892	7·69	2·0399
6·94	1·9373	7·32	1·9906	7·70	2·0412
6·95	1·9387	7·33	1·9920	7·71	2·0425
6·96	1·9402	7·34	1·9933	7·72	2·0438
6·97	1·9416	7·35	1·9947	7·73	2·0451
6·98	1·9430	7·36	1·9961	7·74	2·0464
6·99	1·9445	7·37	1·9974	7·75	2·0477
7·00	1·9459	7·38	1·9988	7·76	2·0490
7·01	1·9473	7·39	2·0001	7·77	2·0503
7·02	1·9488	7·40	2·0015	7·78	2·0516
7·03	1·9502	7·41	2·0028	7·79	2·0528
7·04	1·9516	7·42	2·0042	7·80	2·0541
7·05	1·9530	7·43	2·0055	7·81	2·0554
7·06	1·9544	7·44	2·0069	7·82	2·0567
7·07	1·9559	7·45	2·0082	7·83	2·0579
7·08	1·9573	7·46	2·0096	7·84	2·0592

TABLE OF HYPERBOLIC LOGARITHMS TO FOUR PLACES.

N.	Logarithm.	N.	Logarithm.	N.	Logarithm.
7·85	2·0605	8·25	2·1102	8·65	2·1576
7·86	2·0618	8·26	2·1114	8·66	2·1587
7·87	2·0631	8·27	2·1126	8·67	2·1599
7·88	2·0643	8·28	2·1138	8·68	2·1610
7·89	2·0656	8·29	2·1150	8·69	2·1622
7·90	2·0669	8·30	2·1163	8·70	2·1633
7·91	2·0681	8·31	2·1175	8·71	2·1645
7·92	2·0694	8·32	2·1187	8·72	2·1656
7·93	2·0706	8·33	2·1199	8·73	2·1668
7·94	2·0719	8·34	2·1211	8·74	2·1679
7·95	2·0732	8·35	2·1223	8·75	2·1691
7·96	2·0744	8·36	2·1235	8·76	2·1702
7·97	2·0759	8·37	2·1247	8·77	2·1713
7·98	2·0769	8·38	2·1258	8·78	2·1725
7·99	2·0782	8·39	2·1270	8·79	2·1736
8·00	2·0794	8·40	2·1282	8·80	2·1748
8·01	2·0807	8·41	2·1294	8·81	2·1759
8·02	2·0819	8·42	2·1306	8·82	2·1770
8·03	2·0832	8·43	2·1318	8·83	2·1782
8·04	2·0844	8·44	2·1330	8·84	2·1793
8·05	2·0857	8·45	2·1342	8·85	2·1804
8·06	2·0869	8·46	2·1353	8·86	2·1815
8·07	2·0882	8·47	2·1365	8·87	2·1827
8·08	2·0894	8·48	2·1377	8·88	2·1838
8·09	2·0906	8·49	2·1389	8·89	2·1849
8·10	2·0919	8·50	2·1401	8·90	2·1861
8·11	2·0931	8·51	2·1412	8·91	2·1872
8·12	2·0943	8·52	2·1424	8·92	2·1883
8·13	2·0956	8·53	2·1436	8·93	2·1894
8·14	2·0968	8·54	2·1448	8·94	2·1905
8·15	2·0980	8·55	2·1459	8·95	2·1917
8·16	2·0992	8·56	2·1471	8·96	2·1928
8·17	2·1005	8·57	2·1483	8·97	2·1939
8·18	2·1017	8·58	2·1494	8·98	2·1950
8·19	2·1029	8·59	2·1506	8·99	2·1961
8·20	2·1041	8·60	2·1518	9·00	2·1972
8·21	2·1054	8·61	2·1529	9·01	2·1983
8·22	2·1065	8·62	2·1541	9·02	2·1994
8·23	2·1078	8·63	2·1552	9·03	2·2006
8·24	2·1090	8·64	2·1564	9·04	2·2017

TABLE OF HYPERBOLIC LOGARITHMS TO FOUR PLACES.

N.	Logarithm.	N.	Logarithm.	N.	Logarithm.
9·05	2·2028	9·37	2·2376	9·69	2·2712
9·06	2·2039	9·38	2·2386	9·70	2·2721
9·07	2·2050	9·39	2·2396	9·71	2·2732
9·08	2·2061	9·40	2·2407	9·72	2·2742
9·09	2·2072	9·41	2·2418	9·73	2·2752
9·10	2·2083	9·42	2·2428	9·74	2·2762
9·11	2·2094	9·43	2·2439	9·75	2·2773
9·12	2·2105	9·44	2·2450	9·76	2·2783
9·13	2·2116	9·45	2·2460	9·77	2·2793
9·14	2·2127	9·46	2·2471	9·78	2·2803
9·15	2·2138	9·47	2·2481	9·79	2·2814
9·16	2·2148	9·48	2·2492	9·80	2·2824
9·17	2·2159	9·49	2·2502	9·81	2·2834
9·18	2·2170	9·50	2·2513	9·82	2·2844
9·19	2·2181	9·51	2·2523	9·83	2·2854
9·20	2·2192	9·52	2·2534	9·84	2·2865
9·21	2·2203	9·53	2·2544	9·85	2·2875
9·22	2·2214	9·54	2·2555	9·86	2·2885
9·23	2·2225	9·55	2·2565	9·87	2·2895
9·24	2·2235	9·56	2·2576	9·88	2·2905
9·25	2·2246	9·57	2·2586	9·89	2·2915
9·26	2·2257	9·58	2·2597	9·90	2·2925
9·27	2·2268	9·59	2·2607	9·91	2·2935
9·28	2·2279	9·60	2·2618	9·92	2·2946
9·29	2·2290	9·61	2·2628	9·93	2·2956
9·30	2·2300	9·62	2·2638	9·94	2·2966
9·31	2·2311	9·63	2·2649	9·95	2·2976
9·32	2·2322	9·64	2·2659	9·96	2·2986
9·33	2·2332	9·65	2·2670	9·97	2·2996
9·34	2·2343	9·66	2·2680	9·98	2·3006
9·35	2·2354	9·67	2·2690	9·99	2·3016
9·36	2·2364	9·68	2·2701	10·00	2·3026

TO FIND THE AREA OF THE SPACE BETWEEN A CURVE AND A STRAIGHT LINE.

SIMPSON'S RULE.

In figure 15 let ABCA be the space, AB the straight line, ACB the curve; let AB be divided into an even number of equal parts, say 10, at the points 1, 2, 3, &c.; at the points of division draw straight lines perpendicular to AB to meet the curve, those perpendiculars are called *ordinates.*

Let distances on the ordinates measured with dividers on a scale, be the same as in the figure; then

$$A = \frac{(S+E\times 4+O\times 2)D}{3}$$

Where
A = area.
S = sum of first and last ordinates.
E = sum of all the even ordinates.
O = sum of all the odd ordinates.
D = common distance between the ordinates.

Hence we have the following

RULE.

Add together the first and last ordinates. Four times the sum of the even ordinates, and Twice the sum of the odd ordinates.

Multiply the sum thus found by the common distance between the ordinates, and divide this product by 3, the result is the area.

EXAMPLE.

In figure 15 the curve meets the straight line, so that the first and last ordinates $= O$; that is, $S = O$, let the other ordinates have the values marked on them in the figure, and let $D = 2$; then we have as follows:

$$
\begin{array}{llll}
S = 0. \quad E = & \left\{\begin{array}{r} 1·71 \\ 3·95 \\ 4·54 \\ 4·02 \\ 2·04 \end{array}\right. & \qquad O = & \left\{\begin{array}{r} 3·60 \\ 4·43 \\ 4·54 \\ 3·17 \end{array}\right. \\
 & \overline{16·26} & & \overline{15·74} \\
 & 4 & & 2 \\
E \times 4 = & \overline{65·04} & O \times 2 = & \overline{31·48} \\
O \times 2 = & 31·48 & & \\
 & \overline{96·52} & & \\
D = & 2 & & \\
 & \overline{3)193·04} & & \\
 & \overline{64·35} \text{ Answer.} & &
\end{array}
$$

TO FIND THE MEAN PRESSURE THROUGHOUT THE STROKE.

EXAMPLE.

Steam is admitted into the cylinder at 45 lbs. per square inch above the atmosphere, and is cut off at $\frac{3}{8}$ths of the stroke; required the mean pressure on the piston throughout the stroke, supposing the vacuum to be perfect.

In order to understand this question it is necessary to know something of the expansion of steam.

The following is the law of the expansion of steam; it was discovered by Mariotte:

If a given weight of steam be made to vary its volume without changing its temperature, the *elastic force* of the steam will vary in the *inverse ratio of the volume* it is made to occupy.

Thus—Suppose the distance from the bottom of the piston to the bottom of the cylinder to be 16 inches, and this part of the cylinder to be full of steam at a pressure of 20 lbs. on the square inch, then let the piston be forced down 8 inches so that the steam occupies only half the space it did before, then its pressure will be doubled, that is, on each square inch its pressure will be 20 × 2 = 40 lbs.

Again, let the piston be forced 4 inches further down, so as again to reduce the volume of steam by one half, or to compress it into one quarter of its original volume, then the pressure will be again doubled, and will now be 40 × 2, or 20 × 4 = 80 lbs. on the square inch.

And, in like manner, by making the volume of steam as *small as we please*, we can make the pressure per square inch as *great as we please.*

In figure 16 let ABPQ represent the cylinder, and AP its height, divide AP into 10 equal parts in the points 1, 2, 3, &c., through those points draw lines parallel to the top of the cylinder; then the cylinder will be divided into 10 equal parallograms, and since the steam is cut off at ⅖ths of the stroke, that is at the 4th division of AP, the piston moves over the remainder of the stroke by the expansive force of the steam already in the cylinder.

Let P represent the pressure per square inch when the piston is in the position CD; $P_{\prime}'$ the pressure when it is in the position EF; $P_{\prime\prime}''$ the pressure when it is in the position GH; and so on.

Now the steam is admitted at a pressure of 45 lbs. per square inch above the atmosphere, and the pressure of the atmosphere may be taken at 15 lbs. per square inch, therefore the effective pressure on the piston at the first part of the stroke is 60 lbs. per square inch, and the pressure being constant while the piston is moving from the position AB to the position CD, it is therefore represented by the four equal parallograms above CD, hence 60 lbs. × 4 = 240 lbs. pressure when the piston is at CD.

Let the figure bounded by the straight lines CD, DQ, QR, and the curve RC represent the total pressure of the steam during its expansion. In order to find the value of this pressure proceed as follows :

$$\left.\begin{array}{r}5)240\\ \hline 48\end{array}\right\}\quad \left.\begin{array}{r}6)240\\ \hline 40\end{array}\right\}\quad \left.\begin{array}{r}7)240\\ \hline 34{\cdot}29\end{array}\right\}\quad \left.\begin{array}{r}8)240\\ \hline 30\end{array}\right\}\quad \left.\begin{array}{r}9)240\\ \hline 26{\cdot}67\end{array}\right\}\quad \left.\begin{array}{r}10)240\\ \hline 24\end{array}\right\}$$

Then by Simpson's Rule.

$$A = \frac{(S+E\times4+O\times2)\times D}{3}$$

$$\begin{array}{rcccccrcl}
 & & \left\{\begin{array}{r}60\\24\end{array}\right\} & \left\{\begin{array}{r}48\\34{\cdot}29\\26{\cdot}67\end{array}\right\} & \left\{\begin{array}{r}40\\30\end{array}\right\} & D = 1. & S & = & 84\\
 & & — & — & — & & E\times4 & = & 435{\cdot}84\\
S & = & 84 & 108{\cdot}96 & 70 & & O\times2 & = & 140{\cdot}0\\
 & & — & 4 & 2 & & & & \overline{659{\cdot}84}\\
 & & & \overline{} & O\times2 = 140 & & D & = & 1\\
E\times4 & = & & 435{\cdot}84 & — & & & & \overline{3)659{\cdot}84}
\end{array}$$

Value during expansion 219·95 lbs.
Before expansion 240·00

1,0)45,9·95

Mean pressure throughout the stroke 45·99

TO FIND THE MECHANICAL EFFICIENCY.

Divide the mean pressure by the final pressure, the quotient will be the mechanical efficiency.

Final pressure	**24**	**6)45·99 lbs. mean pressure**
		4) 7·665
Mechanical efficiency		**1·916 Answer.**

SECOND METHOD.

DUE TO MR. McFARLANE GRAY.

Reduce the fraction that the steam is cut off at to a decimal, to 6 places of figures when it is necessary to do so; thus

$$\frac{2}{5} = {\cdot}4$$

Then arrange the solution as follows:

	0	·05	
	1	·1	
	2	·1	
	3	·1	
Cut off	4	·1	
	5	·08	5)·4
	6	·066667	—
	7	·057143	·08
	8	·05	—
	9	·044444	
	10	·02	6)·4
		·768254 = Sum	·066667
		60 lbs. effective pressure	
Mean pressure throughout the stroke		46·095240 lbs.	

This answer differs only about ·1 from the answer by the first method.

Remarks. In this method the quantity ·05 is always put opposite the 0, and the quantity ·1 opposite to 1, 2, 3, &c., to the cut off.

Again; to find the quantities to put down opposite the figures below the cut off; divide the decimal of the cut off, that is in this instance ·4 by the figures below the cut off, that is in this instance by 5, 6, 7, &c.; then proceed as in the solution.

Note. ·4 ÷ 10 = ·04, and the half of this must be taken, as in the solution.

THIRD METHOD

BY HYPERBOLIC LOGARITHMS.

Formula. $$p = \frac{Pa}{b}\left(1+\log\frac{b}{a}\right) = \frac{60\times2}{5}\left(1+\log\frac{5}{2}\right)$$

$$= 12\times2\,(1+\log 2{\cdot}5) = 24\times1{\cdot}9163 = 45{\cdot}9912.$$

Answers 45·99 lbs. Mean pressure throughout the stroke.
1·9163 Mechanical efficiency.

Example 2. Steam is admitted into the cylinder at 52 lbs. per square inch above the atmosphere, and is cut off at $\frac{3}{8}$ of the stroke; required the mean pressure on the piston throughout the stroke; supposing the vacuum to be perfect ?

BY SIMPSON'S METHOD.

Cut off $\frac{3}{8} = \frac{6}{16}$; $16 - 6 = 10.$

Here the cylinder must be divided into 16 equal parts, of which 6 will have full steam.

52 lbs. Guage
15 Atmosphere
——
67 Gross
6 Ports full steam
——
402 Before expansion
——

		67·00............... 1	67·00	57·43
402÷7	=	57·43............... 2	25·13	44·67
402÷8	=	50·25............... 3	——	36·55
402÷9	=	44·67............... 4	*S* 92·13	30·92
402÷10	=	40·2 5	——	26·8
402÷11	=	36·55............... 6		——
402÷12	=	33·5 7	50·25	196·37
402÷13	=	30·92............... 8	40·2	4
402÷14	=	28·71............... 9	33·5	——
402÷15	=	26·8 10	28·71	785·48... 4 *E*
402÷16	=	25·13...............11	——	305·32... 2 *O*
			152·66	92·13... *S*
			2	——
			——	1182·93
			305·32	——

3)1182·93

394·31 during expansion
402·00 before expansion

16)796·31(49·78 lbs. mean pressure throughout the stroke.

Final pressure 25·13)49·78(1·98 mechanical efficiency.

BY McFARLANE GRAY'S METHOD.

Cut off $\frac{3}{8}$ ·0 = ·375

0......... ·05
1......... ·1
2......... ·1
3......... ·1
4......... ·09375
5......... ·075
6......... ·0625
7......... ·053571
8......... ·046875
9......... ·041667
10......... ·01875

4)·375
·09375
&c.

·742113
67 gross pressure at the beginning of the stroke.

5194791
4452678

Mean pressure throughout the stroke 49·721571

BY HYPERBOLIC LOGARITHMS.

Formula.
$$p = \frac{P\,a}{b}\left(1+\log\frac{b}{a}\right) = \frac{67\times3}{8}\left(1+\log\frac{8}{3}\right)$$

$$= \frac{201}{8}(1+\log 2{\cdot}67) = \frac{201\times1{\cdot}9821}{8} = 49{\cdot}8003$$

Answers 49·8 lbs. Mean pressure throughout the stroke.
1·9821 Mechanical efficiency.

Example 3. Steam is admitted into the cylinder at 24 lbs. per square inch above the atmosphere, and is cut off at 7 inches of the stroke, which is 20 inches; required the mean pressure on the piston throughout the stroke; supposing the vacuum to be perfect; also the mechanical efficiency?

BY McFARLANE GRAY'S METHOD.

$\frac{7}{20}$ 20)7·0(·35 decimal of cut off.

Guage 24
Atmosphere 15
Gross 39

	0.........	·05
	1.........	·1
	2.........	·1
Cut off	3.........	·1
	4.........	·0875
	5.........	·07
	6.........	·058333
	7.........	·05
	8.........	·04375
	9.........	·038889
	10.........	·0175

4)·35 ·0875
5)·35 ·07
6)·35 ·058333
7)·35 ·05
8)·35 ·04375
9)·35 ·038889
10)·35 2)·035 ·0175

·715972
39 gross pressure at beginning of stroke.

6443748
2147916

27·922908 lbs. mean pressure throughout the stroke.

BY HYPERBOLIC LOGARITHMS.

Formula. $$p = \frac{Pa}{b}\left(1+\log\frac{b}{a}\right) = \frac{39\times7}{20}\left(1+\log\frac{20}{7}\right)$$

$$= \frac{39\times7}{20}(1+\log 2{\cdot}86) = \frac{39\times7\times2{\cdot}0508}{20}$$

$$= 27{\cdot}99342 \text{ lbs. mean pressure throughout the stroke}$$

Mechanical efficiency 2·0508.

Example 4. Steam is admitted into the cylinder at 38 lbs. per square inch above the atmosphere, the effective pressure of the vacuum is 10·3 lbs. per square inch, diameter of cylinder 5 feet 4 inches, length of stroke 46 inches, cut off 27 inches from the beginning of the stroke, and making 22 revolutions per minute; find the H.P.

TO FIND THE MEAN EFFECTIVE PRESSURE.

BY GRAY'S METHOD.

Cut off $\frac{27}{46}$ = ·586957

	lbs.
Guage	38
Atmosphere	15
Gross	53

	lbs.
Maximum vacuum	15
Effective vacuum	10·3
Back pressure	4·7

0......... ·05
1......... ·1
2......... ·1
3......... ·1
4......... ·1
5......... ·1
Cut off —
6......... ·097826
7......... ·083851
8......... ·073370
9......... ·065217
10......... ·029348

6)·586957
·097826
&c.

·899612
53 Gross pressure at the beginning of the stroke
2698836
4498060
47·679436
4·7 Back pressure
42·979436 Mean effective pressure throughout the stroke.

BY HYPERBOLIC LOGARITHMS.

$$\textit{Formula.}\quad p = \frac{P\,a}{b}\left(1+\log\frac{b}{a}\right) = \frac{53\times 27}{46}\left(1+\log\frac{46}{27}\right)$$

$$= \frac{53\times 27}{46}(1+\log 1{\cdot}70) = \frac{53\times 27\times 1{\cdot}5306}{46}$$

= 47·6149 mean pressure
4·7 back pressure

42·9149 mean effective pressure

TO FIND THE H.P.

$$\text{Formula A, Article 17.}\quad \frac{{\cdot}7854\, d^2\, p\, s\, r \times 2}{33000}$$

$$= \frac{{\cdot}7854\times 64\times 64\times 42{\cdot}97\times 46\times 22\times 2}{33000\times 12}$$

$$\text{By cancelling} = \frac{{\cdot}2618\times 64\times 64\times 42{\cdot}97\times 46}{3000} = 706{\cdot}531 \text{ H.P.}$$

THE INDICATOR.

The Indicator is one of James Watt's useful inventions, but it has been much improved since his time. The one in general use is Richards', it having all the latest improvements, and it is considered superior to any other, owing to the fine adjustment of its working parts. By this instrument we are enabled to tell at a glance what has been going on in the internal parts of the Engine. For instance we can tell if the Slide has too much or two little lead; whether the error be due to the position of the eccentric or the length of the rod, or if the Slide or piston be leaking; if the exhaust be too soon or too late in its action; if the vacuum be good or bad; in fact, every derangement of the Slide or internal parts of the engine are made visible to the eye.

Fig. 1 is a representation of Richards' Indicator. A is a steam cylinder, having a very accurate fitting piston attached to the piston rod B. The cross arms CC work round the outside of the cylinder A, and are used to turn the pencil to and from the paper, also for carrying the parallel motion DEFG. The piston rod is screwed into a single socket (H), and attached by a pair of links (I) to the parallel motion. The pencil J is screwed into a small boss, and is capable of being regulated to suit the distance from the paper, or taken out and pointed. K is the barrel round which the paper is wrapped. The split graduated clasp L shows the pressure of steam and vacuum; the paper, in being placed round the barrel K, is slipped in behind the split graduated clasp; by this means it is held firmly in its place. Inside the barrel K is a cylinder, which contains a coiled spring, which brings the barrel back to its place after it has made a stroke with the engine. At the lower part of this cylinder the grooved pulley M, when the cord works round, will be observed. N are the two small guide pulleys; by slacking the bottom nut O these pulleys can be turned in any desired position to suit the lead of the cord to the engine. The stem of the Indicator, P, is conical, and fits in a corresponding seat in the stop cock Q, where it is held by a coupling, or round nut, R, having two screws of unequal pitch; this arrangement permits the Indicator to be turned round in any position, and tightened up without much trouble. The springs are of different strengths to suit the different pressures; each spring is marked with the scale and pressure, so that if $\frac{1}{8}$ spring be used, the diagram will be drawn to a scale of $\frac{1}{8} =$ lbs., and so on for all other scales and pressures. The paper that is used is properly prepared metallic paper, made specially; the pencil J is usually of brass wire. In measuring the vacuum, or the pressure below the atmospheric line to the lower part of the diagram, it is usual to measure in inches, because 30 inches of mercury are equal to 15lbs. pressure, or, in other words, the atmospheric pressure is equal to 30 inches of mercury; therefore 1lb. pressure is equal to 2 inches of vacuum.

How to take a Diagram.—1st. Unscrew the nut or cylinder cover S, lift out the piston, cross arms, and parallel motion altogether, unscrew the piston rod from the socket, select the spring to suit the pressure, then place it on the rod; a brass nut will be seen at each end of the spring which is screwed on to the rod, screw the rod into the socket, replace the piston in the cylinder, being careful not to scratch the inside of the cylinder, then screw on the cover. 2nd. Lift off the paper barrel, place the paper tightly round it, having the end behind the split graduated clasp, be careful and see that the paper is lying smooth against the barrel; having done this replace the barrel. 3rd. Fix the gear for reducing the stroke of the engine to the travel of the Indicator barrel, which is usually about 5 inches; always try and get the cord as short and direct as possible; when a long cord is used it often stretches and spoils the shape of the diagram. Now open the cocks at each end of the cylinder to blow out any grease or dirt that may be in the pipes; next close the cocks and screw on the stop cock Q, then screw on the Indicator by means of the round nut R, attach the cord from the reducing gear to the cord from the paper barrel; this is accomplished by having a brass hook on one end of the cord and a loop on the other end; open one of the cylinder cocks, then open the stop cock Q, and allow the indicator to work a few strokes, shut the stop cock Q, and turn the cross arms CC so that the pencil touches the paper; it will then trace a horizontal line which is called the atmospheric line, because the atmosphere acts on both sides of the piston; when the stop cock Q is shut air passes through the small hole T to the under side of the piston, thus placing the piston in equilibrium; now open the cock Q and the cock to the top of the cylinder, and the pencil will rise at once and trace a diagram of the work done at the top of the piston in one revolution; shut the cock to the top of the cylinder and open the bottom cock, the pencil will now trace a diagram of the work done under the piston in the same time; shut the cocks, unloop the cord, take off the barrel and detach the paper, and the diagrams are completed.

Now look at *Fig.* 2, and follow the pencil as it traces the diagram; suppose the pencil stands at the atmospheric line A, as soon as steam is admitted to the Indicator cylinder the pencil will rise to C, the highest pressure, and remain there till the steam is cut off. In the meantime the barrel with the paper will revolve with the stroke of the engine, tracing the horizontal line CD; at D the steam is cut off by the slide, and it now begins to fall and to trace the expansion line E; at F the exhaust port opens, and the pencil falls suddenly owing to the release of the steam to the condenser; at G it commences the return stroke, and traces the vacuum line; on arrival at H the exhaust port is closed before the end of the stroke, producing compression, or the lead of the valve comes into action, forcing the pencil up to A; from this point the pencil will trace the same curve as the engine makes another revolution. The space between the bottom of the diagram or vacuum line to the line of perfect vacuum is called the back pressure. The diagram selected is from the top of the piston, but both sides are traced by the same process.

When accuracy is required a diagram should be taken from both top and bottom of the piston, because the diagram taken from the top of the piston only shows the pressure and vacuum on the top; it does not shew what is going on below the piston; it is generally found that there is a good deal of difference between the diagrams taken from the opposite ends of the piston, so that it is necessary to have diagrams from both top and bottom of the piston to get the mean pressure, so as to calculate the indicated horse power. If the actual state of the engine be required, it will be necessary to examine into what is passing above and below the piston, because the errors in one part may have no connection with the errors in another; this will be the case if the slide is too long or too short on one side, in which case the upper port may be properly covered and the lower one not so, or the slide face on one side may be leaky and tight on the other, so that if cards from both sides are taken it will detect all errors, and prevent the attempt to improve the error of one side to the disadvantage of the other.

In *Fig.* 3 the slide rod is too long; the left hand card or top card shews that the steam is cut off too soon, and that the exhaust opens too soon and closes too late, and has no lead, as will be seen by the admission line slanting to the right at *a*. In the right hand card the steam is cut off too late, exhaust opens late and closes soon, and has too much lead as seen by the slanting line at *b*.

In this case a liner taken from under the eccentric rod foot, or lowering the slide on the rod, will cure this; in other words, divide the lead.

In *Fig.* 4 the slide rod is too short. The top card shows she opens exhaust too late and closes too soon, producing too much cushion, and has too much lead; the bottom card shows steam cut off too soon, exhaust opens too soon and closes too late, and has no lead. In these diagrams the opposite effect will be observed to have taken place to Fig. 3. To remedy this, the eccentric rod requires a liner under the foot, or the valve wants lifting up on the slide rod.

Fig. 5 shews the sheave is too far advanced. Top and bottom cards shew that she opens to steam too soon and closes too soon: opens to exhaust too soon and closes exhaust too, and has too much lead. In this case all the movements are too soon in both top and bottom cards; the sheave requires to be shifted back a little. For proper position of sheave see further on.

Fig. 6 shews the sheave is not enough advanced. Top and bottom cards shew that she opens to steam too late, opens exhaust too late and closes exhaust too late, has no cushion or lead. In both cards all the movements are too late. In this case the sheave requires to be shifted forward a little. The difference between shifting the sheave or altering the length of the rod is easily seen by noting the following points:—If the steam is admitted too soon and exhaust opens too late, or if steam is admitted too late and exhaust opens too soon, it is the fault of the rod; but if the steam is admitted too soon and exhaust opens too soon, or steam is admitted too late and exhaust opens too late, the fault in these cases lies in the position of the sheave. By this you see the points of admission and exhaust, when working similar, are governed by the position of the sheave; but if the points of admission and exhaust be dissimilar, it lies in the fault of the rod.

In *Fig.* 7 the top card is good, but the bottom card has too much lead. In this case take a liner out from under the eccentric rod foot equal to half the lead, then the movements of both cards will be too soon ; this will require the sheave shifted back a little.

Fig. 8 shews that the piston has been leaking in both the up and down stroke at a certain part, or that the cylinder is slack in the middle, as shown by the rise in the back pressure.

In *Fig.* 9 on the top card at the steam corner there is a loop. This is owing to the Indicator piston shooting straight up on admission of steam. While the piston of the engine is for a moment stationary on passing the centre, when the engine piston begins to move this line falls suddenly, forming the loop ; the bottom card will be observed to have too much compression, thus wasting power. To remedy this, notice that the exhaust opens late ; therefore if a piece is chipped off the exhaust edge of the valve, it will open sooner and close later, doing away with so much compression.

Fig. 10 shews that the slide has been leaking on the bottom face. It will be seen by the rise of the pressure at *d* that fresh steam has been admitted after it has been cut off.

Fig. 11 shews by the steam lines slanting instead of being horizontal that the steam has been throttled, or that the pipes or ports are too small for the cylinder.

Fig. 12 shews a pair of cards throttled by the link at 42 strokes per minute. In these diagrams nearly the whole areas are below the atmospheric line, but on the left hand corner of one of the Figures a loop is formed, which often appears in engines employing the link, the meaning of which it is necessary to explain. The extreme point of the diagram in every instance answers to the length of the stroke, and if the steam is put up in the cylinder by the exhaust being closed before the end of the stroke, or if steam be allowed to enter before the end of the stroke, the pencil will rise to its highest point before the stroke is ended, and as the paper on the barrel continues to move onward, the upper part of the loop is formed. If the pressure within the cylinder when the piston returns were to be precisely the same as when the piston advanced during this part of the stroke, the loop would be narrowed to a line. But as the advance of the piston when the valve is very little open somewhat compresses the steam, and at its recession, when the valve is very little open, causes it to be wire-drawn. The pressure while the piston advances and retires through this small distance, although the cylinder is open to the boiler by means of a small orifice, will not be precisely the same, and the higher pressure will form the upper part of the loop, while the lower part will be formed by the lower pressure. By following the outline of the left hand diagram, it will be seen that the steam begins to be compressed within the cylinder when about three-fourths of the stroke has been completed, and the pencil consequently begins to rise somewhat above its lowest point ; but as the vapour within the cylinder is very rare, the rise is very little until the piston is about one-eighth part of the stroke, or about eight inches from the end of the stroke, the slide valve is slightly opened, when the piston of the Indicator is compelled to ascend to the point answering to the pressure within the cylinder thus produced. As the opening from the boiler continues, and the piston, by advancing against the steam, instead of receding from it, compresses rather than expands the steam admitted into the cylinder, the pressure continues to rise somewhat to the end of the stroke, when the piston of the engine having to move in the opposite direction, the steam within the cylinder will be expanded, and any that may be still entering will be wiredrawn in the contracted passage, and the pressure will fall; under these circumstances a loop will be formed at the corner of the diagram, such as shewn to exist at the left hand corner of Fig. 12. The reason why there is no corresponding loop at the right hand corner of the right hand diagram, is simply because the valve is differently set at one end of the engine from what it is at the other, and the angle of the eccentric rod will generally cause some small difference in the action of the valves at the different ends of the engine.

Fig. 13 shews two diagrams taken from the top of an engine to show the difference between throttling and expansion working. The card marked 1, 2, 3, 4 will represent the one obtained by throttling with the expansion off. The card marked ABCDE will represent the one obtained when working with the expansion valve. The number of revolutions being the same in both cases, it will be seen when the steam is throttled or wire-drawn, a greater quantity is used and less work done by it. In throttling scarcely any of the curve rises above the atmospheric line, while the vacuum is pretty full. In the expansion card the steam has risen to a good height, and the expansion curve has formed quickly. At the point where exhaust opens, the diagram with throttling is much higher than the expansion diagram at that point, showing that there is more steam in the cylinder in the former than in the latter case. Therefore, in order to do the same amount of work, an engine will require less steam when working expansively than when using the throttle valve.

Fig. 14. These diagrams were taken from a screw engine, and are splendid specimens of expansion cards. On the left hand corner of the right hand figure will be observed a loop, caused through water being in the cylinder. The moment the cylinder relief valve was opened it disappeared.

Fig. 15. Diagrams taken from both cylinders of a pair of compound engines, having no steam jacket on the low pressure cylinder.

Fig. 16. Diagrams taken from both cylinders of a pair of compound engines of the same dimensions as the engines that Fig. 15 were taken from. These engines were jacketed on the low pressure cylinder, and it will be observed, by looking at the low pressure cards, the rise of pressure above the atmospheric line in all the grades, thus gaining a lot of power over the cylinder with no jacket. The cards from both

engines are good, showing all the different grades of expansion clearly, and especially the difference in the pressures in the low pressure cylinders, owing to the one being jacketed and the other not.

***Fig.* 17. Cards taken from a compound engine. On the low pressure card vibration of the Indicator pencil will be observed, caused by the Indicator piston being too tight, or the Indicator spring being too stiff.**

***Figs.* 18 and 19. The irregular lines and small jumps seen on these cards are also caused by the vibration of the Indicator pencil through the spring being too stiff.**

***Figs.* 20 and 21 are specimens of Indicator cards taken from a compound engine. In Fig. 20 the steam is cut off at one quarter the stroke. Fig. 21 the steam was cut off at ⅜ of the stroke. These cards were taken from an engine employed in the making of gas, the fuel used being coke in Fig. 21, the consumption being 4·8lbs. per I.H.P. In Fig. 20 Welsh coal was used, the consumption being reduced to 2·8lbs. per I.H.P.**

***Fig.* 22. Cards taken from a pair of compound screw engines, with the indicated horse power worked out.**

Fig. 23. Cards from a pair of compound screw engines, with the indicated horse power worked out. The process is as follows ;—Divide the cards into ten equal parts, as shewn in Figs. 22 and 23. The advantage of dividing it into ten parts instead of seven or eight parts is that the division by ten is accomplished by merely shifting the position of the decimal point ; a division of ten parts is quite accurate enough for all practical purposes. Measure the width of the card in the middle of each division, as shown by the dotted lines ; add the sum together and divide by ten, or, as stated before, shift the decimal point one figure to the front, which amounts to the same thing. This will equal the mean pressure on that side of the piston. Proceed with the other card in the same way. Having got the mean pressure on each side of the piston, add both together and divide by two ; the sum of this equals the mean pressure in the cylinder. Then proceed as follows :—

$$\frac{\text{area of cylinder} \times \text{mean pressure} \times \text{piston speed per min.}}{33000} = \text{the}$$

indicated horse power obtained from that cylinder. The revolutions per minute multiplied by twice the length of stroke in feet equals the piston speed per minute.

Fig. 24. Cards from the cylinder of an oscillating paddle wheel engine, the diameter of the cylinder 54″, stroke 6′ 0″.

Fig. 25. Diagrams from a pair of compound screw engines, built on the Tyne.

Fig. 26. Diagrams from a pair of compound screw engines built on the Wear, shewing the indicated horse power worked out.

Fig. 27. Diagrams from pair of compound screw engines built on the Tyne.

Fig. 28. Diagram taken from the top of high pressure cylinder, and diagram taken from the bottom of low pressure cylinder, pieced together at the same scale. In the working of a compound, when the high pressure cylinder exhausts into the low pressure cylinder, the amount of work done in a stroke depends on the proportion that the two cylinders bear to each other, or the number of times the steam is expanded. If the two cards were put together in the proportion that the cylinders bear to each other, the cards would then represent a card similar to what would be obtained from a single cylinder of the same cubic contents, having the same initial pressure. In Fig. 20 the high pressure cylinder is 26" dia., and the low pressure cylinder is 52" dia., the stroke being 30".

Fig. 29 shews the cards placed together, the cylinders having a proportion of 1 to 4; therefore the high pressure card in Fig. 28 is reduced one-fourth of its stroke, as shown at A. The low pressure card remains the same, but is reversed in position to form the expansion curve, as shown at B. It will be seen by the dotted line the form the expansion curve would have taken if the steam had been expanded in one cylinder of capacity and initial pressure equal to the compound cylinder. The loss of pressure between the joining of the two cards is owing to some peculiarities in passing the steam from one cylinder to the other.

Fig. 30. Cards from a pair of compound screw engines built on the Tyne, showing the indicated horse power worked out.

Fig. 31 shews the form of card obtained when the steam is throttled by the link.

Fig. 32. Cards taken from both cylinders of a compound engine throttled by the link, the gear being two turns in and the throttle valve full open.

Fig. 33. Cards from compound screw engines, showing the different grades of expansion by the link, from full gear to 1¼" turn in of gear. Working at full gear the revolutions were 62; gear ¼", revolution reduced to 61; gear ½", revolution 59; gear ¾", revolution 58; gear 1", revolution 56½; gear 1¼", revolution 53½. Vacuum in condenser ranged from 26 inches down to 24 inches.

Fig. 34. Cards taken from a single cylinder engine fitted with Corlis's valves. The cards show a nice clean cut off and expansion line, showing the instantaneous action of these valves.

Fig. 35. Diagrams taken from one pair of compound engines, showing the various grades of expansion. The vessel is fitted with two pairs, high pressure cylinders being 22" dia., and low pressure cylinders 38" dia., the stroke being 6′ 0". These engines drive feathering paddle wheels 21′ 0" dia., each wheel having 16 floats 10′ 0" × 2′ 6" broad.

Fig. 36. Cards taken from a pair of compound screw engines having the cylinders and covers jacketed, high pressure slide cutting off at ·7 of the stroke, and the low pressure slide cutting off at ·5 of the stroke.

Fig. 37 shows cards taken from a compound screw engine working at full gear, and also with the gear four turns in, showing a very light consumption of coal. These cards speak for themselves, and require no comment.

Fig. 38. Cards taken from a single cylinder engine used for driving the machinery in a cotton mill in Lancashire. The consumption of coal per I.H.P. is also shown.

Fig. 39 shews diagrams taken from a three-cylinder compound screw engine. The high pressure cylinder is placed above the intermediate one, the same piston rod serving for both cylinders. The low pressure cylinder is placed alongside of the intermediate one. The remainder of the particulars will be seen on the cards.

Fig. 40. Diagrams from locomotive engines. In No. 1 card it will be seen that the admission is small, by the slight falling off in the steam line. This could be remedied by increasing the length of the port, or the travel of the valve. No. 2 card is much better in this respect, the steam line running out straight, and showing a full and even pressure until the point of cut off is reached. Diagram No. 3 shows an enormous amount of compression when linked up; while No. 4 is linked up further than No. 3, and is much better in this respect, as seen by the compression line running very little above the steam line.

Figs. 41 and 42 are specimens of Friction diagrams. Fig. 41 is taken from a screw engine, having the propeller shaft disconnected at the first coupling. Fig. 42 is taken from a paddle wheel engine, with the paddle wheels disconnected. It is seldom that friction diagrams are taken, unless for experiment, as there is very great risk attending the taking of them. For all practical purposes the friction is usually taken at 1lb, pres. per square inch on the piston for large engines, and 2lbs. for small engines. The friction of large engines is less in proportion than small engines.

The latest experiment of this kind was carried out with the engines of H.M. twin screw despatch vessel "Iris." This vessel is fitted with two sets of engines, each set having two high pressure cylinders 41 inches diameter, and two low pressure cylinders 75 inches diameter, having a stroke of 3′ 0". Each set of engines were kept running steadily while two sets of diagrams were taken. The port engine running at 87·5 revolutions per minute gave 202 indicated horse power, and the starboard engine at 90·5 revolutions per minute gave 196 indicated horse power, or together 898 indicated horse power was expended in dead load friction. The trials at all speeds shewed that the starboard engine worked with the least amount of friction.

Fig. 43 shows diagram taken from an air pump. At the point A the pencil begins to ascend, until about two-thirds of the stroke of the pump has been performed, when at the point C the delivery valve begins to open, and somewhat reduces the pressure, as will be seen by the wave in the diagram. At D the water in the pump has attained its greatest pressure. From this point the pressure consequently falls to E. After the water has been discharged, the barrel of the Indicator moving in the meantime traces the line from E to F, when it commences another stroke.

Fig. 44 are Mr. Spence's diagrams showing the difference in discharge pressure of double-acting pumps. No. 1 diagram is from a circulating pump, shewing a continuous discharge, and also shewing that the bucket had not too much clearance at the ends of the pump, as is generally the case. The cause of the discharge continuing horizontal for such a length, shows that the bucket had to force the water through the tubes of the condenser. No. 2 diagram is from an injector pump, showing a rapid discharge. No. 3 diagram is from a surface condenser air pump. This card is below the atmospheric line, showing the discharge pressure to be very low. At the return stroke it shows that there was a little pressure, as seen by the slanting line.

Fig. 45 shews a diagram taken from a feed pump. At the point A the stroke commences, at B the delivery valve opens, and at C the feed check valve on the boiler opens. From D to E the water has reached its highest pressure. This horizontal line shows a continuous discharge. On the water being discharged the pencil falls to O, and continues so to A, the commencement of the stroke. The reason that part of the pressure at F is below the atmospheric line is through the pet cock not admitting sufficient air to soften the shock of the ram upon the water.

THE SLIDE VALVE.

Fig. 46 is an illustration of the most common form of the Slide Valve, used extensively in the present day. The different parts are very plainly marked, and will be readily understood without any description. Lap on the steam side is the distance the valve covers or stands over the outer edge of the steam port. When the valve is at its mid-stroke, referring to the above Figure, the lap is from the dotted line to the outside edge of valve marked A.

Lap on the exhaust side of the valve is the distance that the valve stands over the side of the steam port next to the exhaust port, as shewn by the dotted line marked B.

The lead of the valve is the distance that the port is open to steam when the crank is at its dead points.

By the angular advance of the eccentric, is to be understood the angle at which the eccentric radius stands in advance of that position which would bring the slide to its mid-stroke when the crank is at its dead points.

Full steam is the position of the valve when fully open, and the piston is continuing in its motion.

Cut off is the position of the valve when it has just closed the port against the admission of steam.

In expansive working engines there are various descriptions of valves used. In the Cornish engine the double beat valve is used; in slow working engines, such as pumping engines, we have valves lifted by cams arranged to drop at the proper time, and in quick running engines we have the Corless valve moved by a series of link work. But the most common mode of expansion is to have one Slide Valve on the back of the other, or on the back of the chest of the main valve. By this contrivance it is possible to cut-off at almost any part of the stroke. There is also expansion by the link, which shortens the throw of the valve and increases the lap, but this is not a pure cut-off, but a mixture of throttling and cut-off.

Expansion by means of lap on the main valve comes next, but this cannot be carried to any great extent. About two-thirds of the stroke is the earliest point at which the main Slide Valve should close the steam port. The method of setting the Slide Valves, so that they will admit and shut out the steam at the proper time, is of the greatest importance, and as the position of the eccentric sheave governs the working of the slide, we will now explain the manner in which they are set:—

In *Fig.* 47 the stroke of the crank is 24 inches, and the travel of the Slide Valve is 5¼ inches; the outside lap is 1¼ inches, and the lead of the valve is ⅛ of an inch. First draw two centre lines AB and CD at right angles to each other; from the centre of the two lines marked O draw a circle equal to the stroke of the crank, and from the same centre describe another circle equal to the travel of the valve; next suppose that the point P represents the position of the crank pin when at the top of its stroke, then from the centre O measure down on the centre line CD a distance equal to the lap and lead added together, which in this case is 1⅝ inch. From this point draw a line parallel to the centre line AB until it touches the circle equal to the travel of the valve; from these points to the centre O draw the angular lines QO and RO, and each line will be the centre of the eccentric sheave when the crank is at its top centre. If the crank moves in the direction indicated by the arrow, Q will be the centre of the go-ahead eccentric sheave, and R will be the centre of the go-astern eccentric sheave.

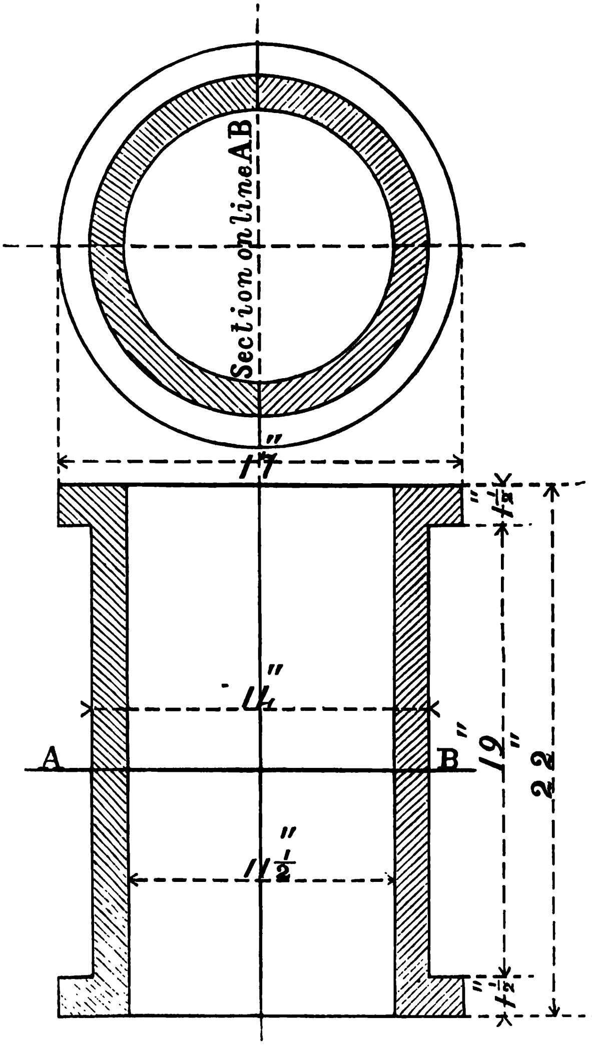
Fig. 1 shows the position of the crank when the piston is at half stroke. It will be seen by the Figure that the connecting rod is a radius whose arc intersecting with the centre line of motion will denote a relative position for the piston at any part of the stroke, and therefore in no case can the angle of the crank be alike when the position of the piston are of equal distances from the ends of the stroke. It is also to be remarked that from the angularity of the connecting rod, with equal lap at both ends of the valve, steam is cut off sooner in the up stroke than in the down stroke; this can be remedied by increasing the lap on the top side of the valve, but it should be remembered that the periods of release are similar. By this it will be seen that the difference in the Indicator diagrams from the top and bottom of the cylinder will be different, as is explained in another portion of this book treating on the Indicator.

In *Fig.* 2 the piston is shewn at the top of its stroke, the crank being on the top centre. The point G is the position of the centre of the eccentric sheave at the instant of admission; then the point H, that is the centre of the dotted line, must be the position of the centre of the eccentric sheave when the steam is shut off, and the crank will have reached the position shewn in Fig. 3, called the point of cut-off in the down stroke. At R we have the position that the crank pin will be in, but we require the distance the piston has travelled down before the steam was cut off. Therefore, as stated in Fig. 1, that the connecting rod was a radius denoting the position of the piston at any part of the stroke, it therefore shews that we will have to take the radius of the connecting rod and describe the arc of the circle, passing through the centre of the crank pin to the centre line of the engine; then the distance measured down from the crank circle to the arc intersected by the connecting rod radius is the distance travelled by the piston when the steam was cut off. In this case it measures 16¼ inches on the diagram.

Fig. 4 shews the same method carried out in reference to the up stroke. This diagram shews that the steam was cut off after the piston had travelled 14¼ inches. By this process any engineer, with the aid of a pair of compasses, can tell with very little trouble where any engine is cutting off the steam. The scale used in the diagrams is too small for any degree of accuracy, and in laying down the diagrams we would advise a scale of three inches to the foot.

VOLUME AND WEIGHT OF A CIRCULAR BRASS BEARING.

Question. What is the weight of a pair of brasses 22" long overall, diameter of journal 11½", diameter of seat 14", diameter of flanges 17", thickness of each flange 1½", and the weight of 1 cubic inch of brass ·3 of a lb.?



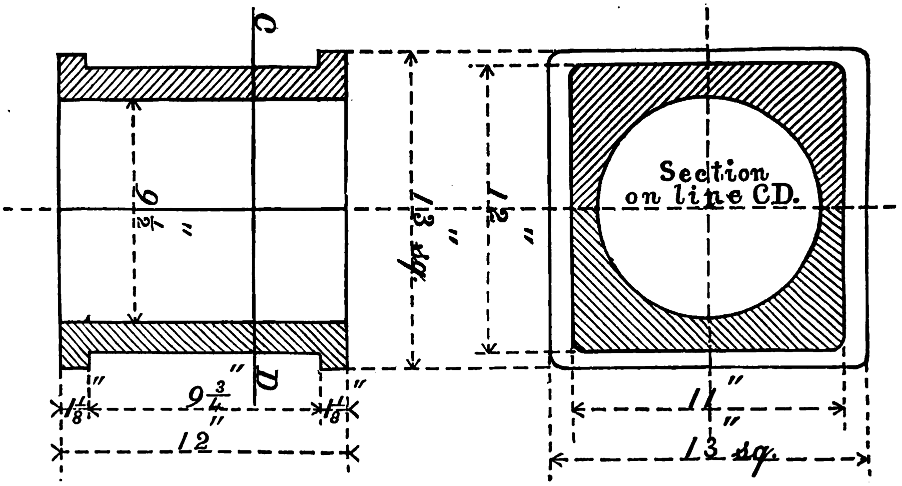
Note. The solution to this question, given in page 76 is erroneous;

substitute the following solution, which is deduced from the application of Article 11 to the preceding figure.

$$\text{Weight} = \left\{(14^2 \times 19 + 17^2 \times 8) - (11{\cdot}5^2 \times 22)\right\} \times {\cdot}7854 \times {\cdot}3$$

$$= 896{\cdot}19508 \text{ lbs. Answer.}$$

VOLUME AND WEIGHT OF A PAIR OF RECTANGULAR BRASSES.



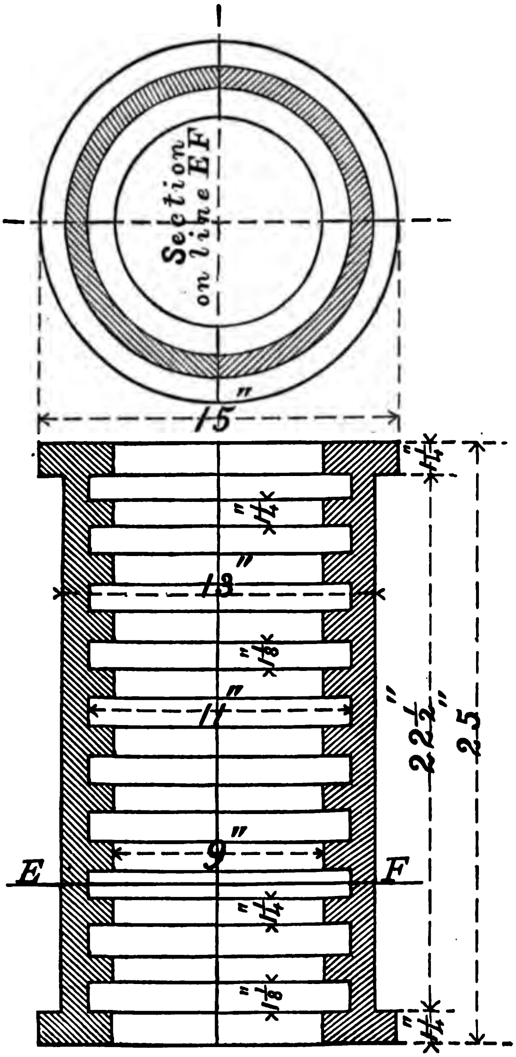
A pair of rectangular brasses is 11″ wide, 12″ deep, and 12″ long, the shaft is 9½″ diameter, and the flanges 13″ square, and 1⅛″ thick; what is the weight of the brasses, allowing ·3 of a lb. per cubic inch.

By the application of formula A, Article 90, and formula A, Article 10, to the preceding figure, we obtain the following solution:

$$\text{Weight} = (11 \times 12 \times 9{\cdot}75 + 13 \times 13 \times 2{\cdot}25 - {\cdot}7854 \times 9{\cdot}5 \times 9{\cdot}5 \times 12) \times {\cdot}3$$

$$= 244{\cdot}99854 \text{ lbs. Answer.}$$

WEIGHT OF A THRUST BLOCK BEARING.

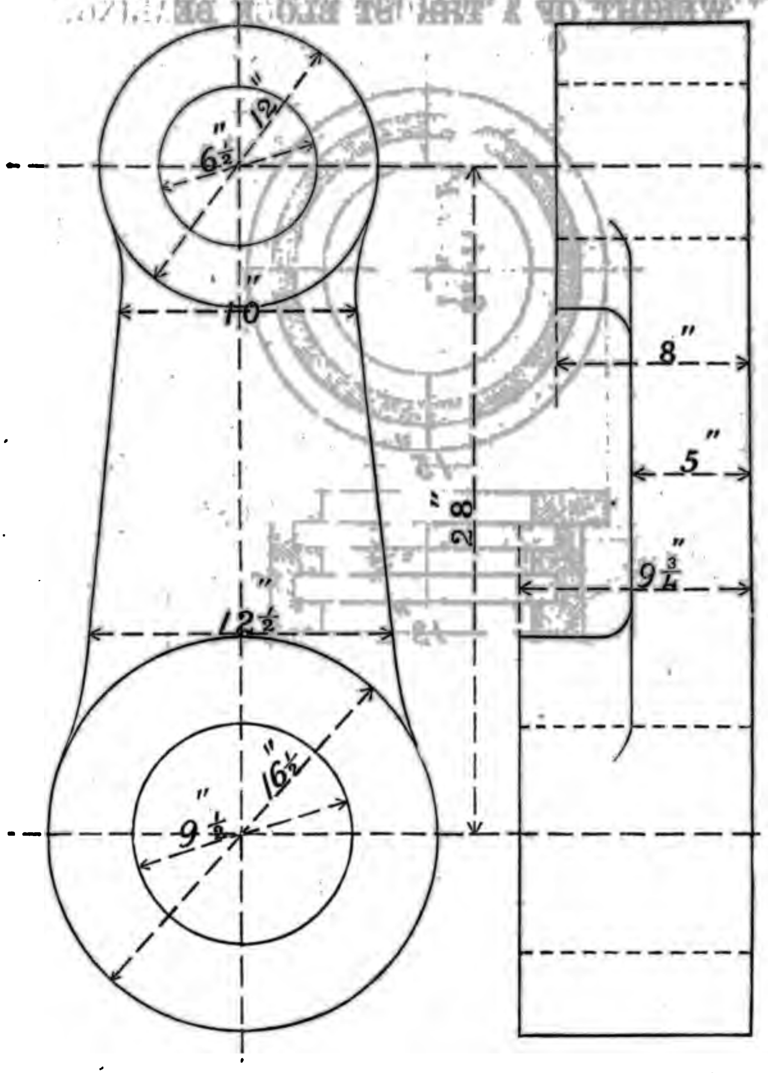


By the application of formula A, Article 11, to the preceding figure we obtain the following solution to question 9, page 164.

$$\text{Weight} = \left\{(13^2-9^2)\times 22{\cdot}5+(15^2-9^2)\times 2{\cdot}5-(11^2-9^2)\times 11{\cdot}25\right\}\times{\cdot}7854$$

$$\times{\cdot}3 = 445{\cdot}3218 \text{ lbs. Answer.}$$

WEIGHT OF A CRANK FOR A PADDLE SHAFT.



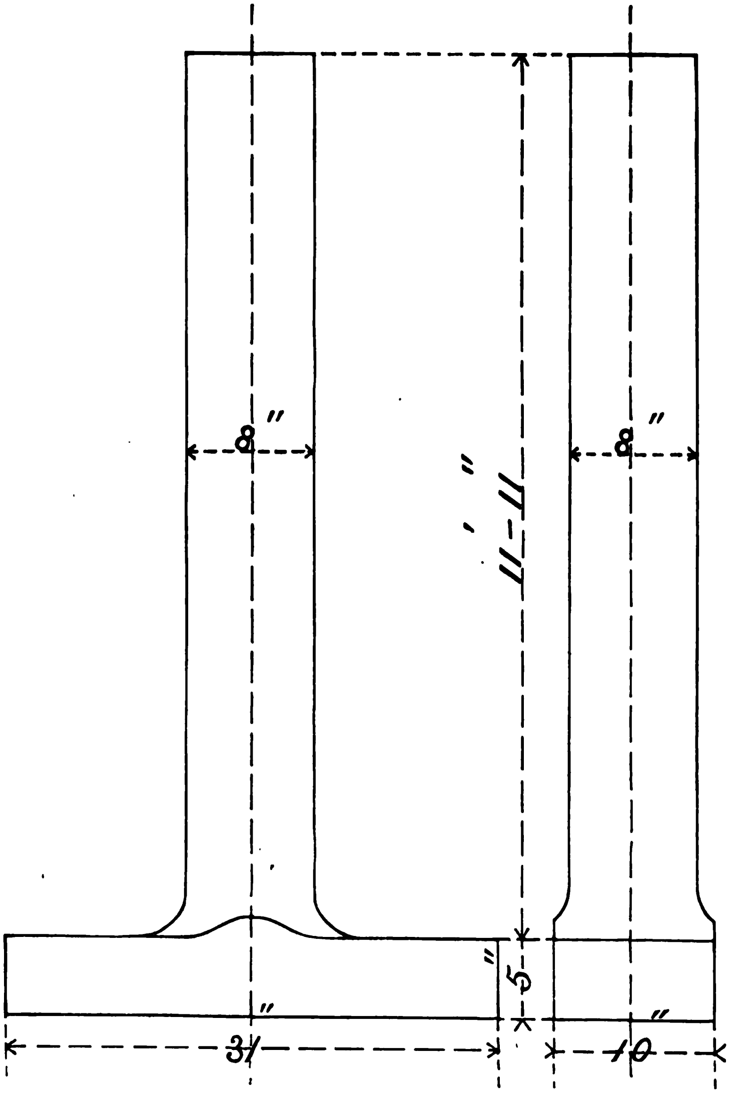
By the application of formula A, Article 11, and formula A, Article 9, to the preceding figure, we obtain the following solution to question 11, page 92.

$$\text{Cubic inches in bosses} = \cdot7854\left\{(12^2 - 6\cdot5^2)\times8 + (16\cdot5^2 - 9\cdot5^2)\times9\cdot75\right\}$$
$$= 2088\cdot0079$$

$$\text{Cubic inches in bar} = 18\cdot5\times11\cdot25\times5 = 1040\cdot625.$$

$$\text{Weight of Crank} = \frac{2088\cdot0079 + 1040\cdot625}{3\cdot6} = 858\cdot7869\ \text{lbs. Answer}$$

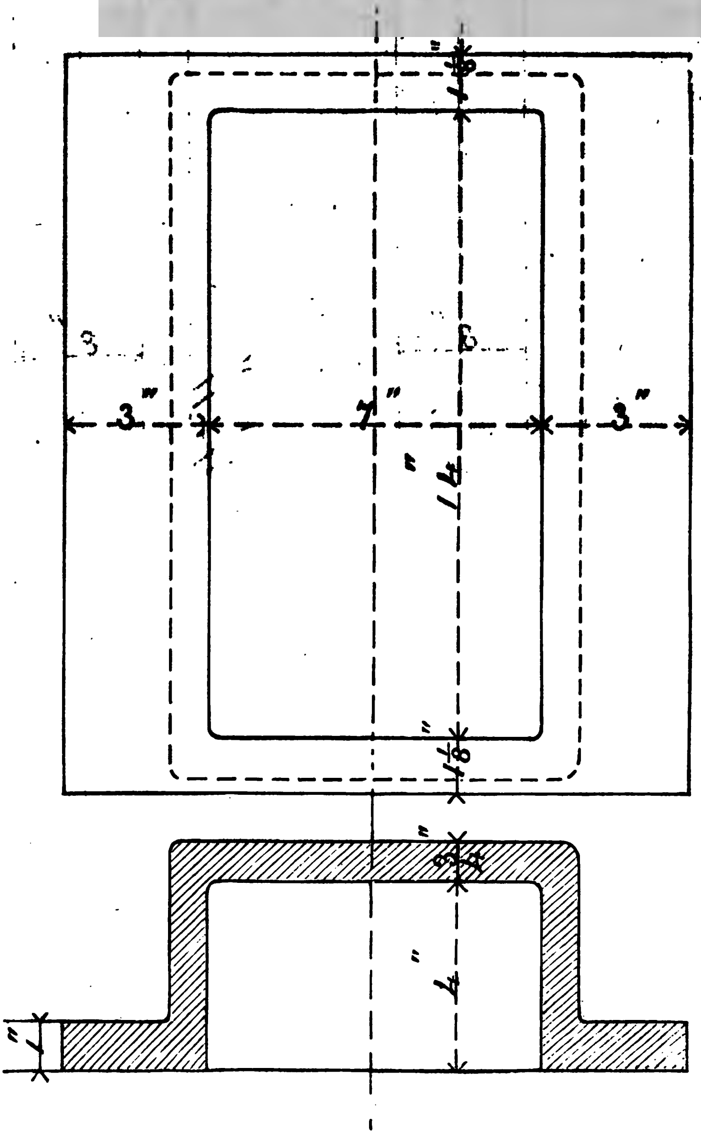
WEIGHT OF A T-HEADED PISTON ROD FOR AN OSCILLATING ENGINE.



By the application of formula A, Article 10, and formula A, Article 9, to the preceding figure, we obtain the following solution to question 4, page 104.

$$\text{Weight} = \frac{\overset{\text{rod.}}{(\cdot7854 \times 8^2 \times 143)} + \overset{\text{T-head.}}{(31 \times 10 \times 5)}}{3\cdot6} = 2427\cdot217 \text{ lbs.}$$

7. Sketch a slide valve to be worked by a hooped spindle, the hoop surrounding the body of the valve, the port in the valve is 14" by 7", the breadth of the face at each end is 3", and at each side $1\frac{1}{8}$", the recess is 4" deep rectangular, the thickness of face is 1" and the thickness of the rest of the valve is $\frac{3}{4}$"; what is the weight of the valve, allowing 8·9 cubic inches of cast iron to weigh 1 lb ?



The volume of the face is equal to the difference in the volumes of two solids, of which the greater is a solid of the dimension of the face, and the other is a solid of the dimensions of the ports. In like manner, the volume of the body is equal to the difference of the volumes of two solids, and the volume of the valve is equal to the sum of the volumes of the face and body. Hence

FACE.

$$\left.\begin{array}{llcll}
\text{Length} & = & 14+1\tfrac{1}{8}+1\tfrac{1}{8} & = 16\tfrac{2}{8} & = 16{\cdot}25 \\
\text{Breadth} & = & 7+3\ +3 & & = 13
\end{array}\right\}\ \text{lineal inches.}$$

$$\left.\begin{array}{lll r}
\text{Outside volume} & = & 16{\cdot}25\times 13\times 1 & 211{\cdot}25 \\
\text{Port volume} & = & 14\quad\times\ 7\times 1 & -98{\cdot}00 \\
 & & & \overline{} \\
\text{Face volume} & & & 113{\cdot}25
\end{array}\right\}\ \text{cubic inches.}$$

BODY.

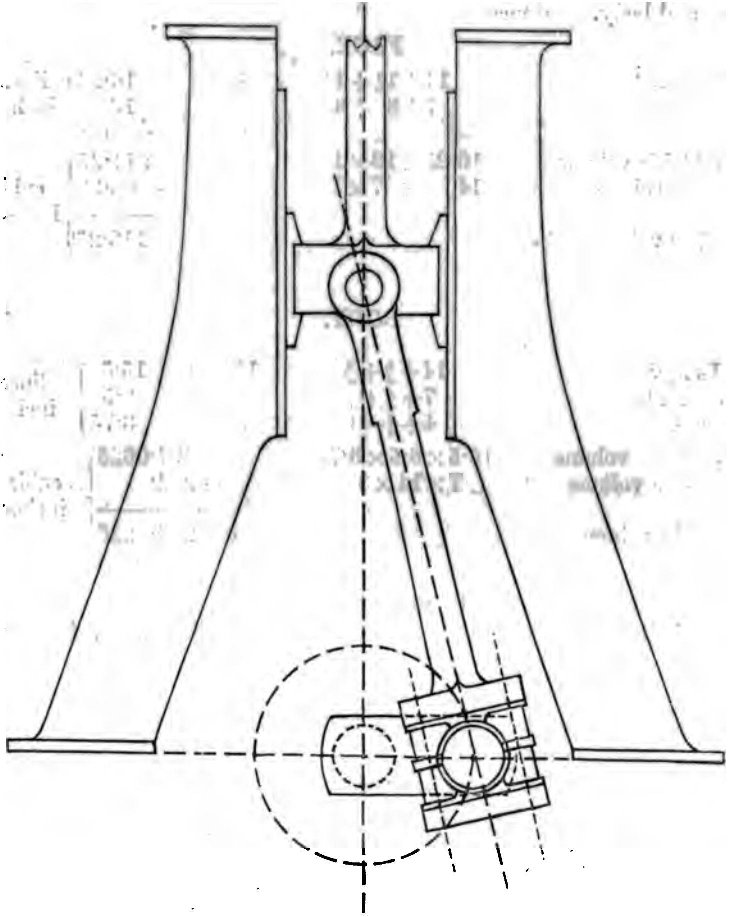
$$\left.\begin{array}{lllll}
\text{Length} & = & 14+\tfrac{3}{4}+\tfrac{3}{4} & = 15\tfrac{1}{2} & = 15{\cdot}5 \\
\text{Breadth} & = & 7+\tfrac{3}{4}+\tfrac{3}{4} & = 8\tfrac{1}{2} & = 8{\cdot}5 \\
\text{Depth} & = & 4+\tfrac{3}{4}-1 & = 3\tfrac{3}{4} & = 3{\cdot}75
\end{array}\right\}\ \text{lineal inches.}$$

$$\left.\begin{array}{llll r}
\text{Outside volume} & = & 15{\cdot}5\times 8{\cdot}5\times 3{\cdot}75 & = & 494{\cdot}0625 \\
\text{Inside volume} & = & 7\times 14\times 3 & = & -294{\cdot} \\
 & & & & \overline{} \\
\text{Body volume} & = & & & 200{\cdot}0625
\end{array}\right\}\ \text{cubic inches.}$$

$$\text{Weight} - \frac{113{\cdot}25+200{\cdot}0625}{3{\cdot}9} = 80{\cdot}337 \text{ lbs. Answer.}$$

SKETCH SHEWING THE POSITION OF GREATEST STRAIN.

Question 5, page 105, and question 8, page 150.



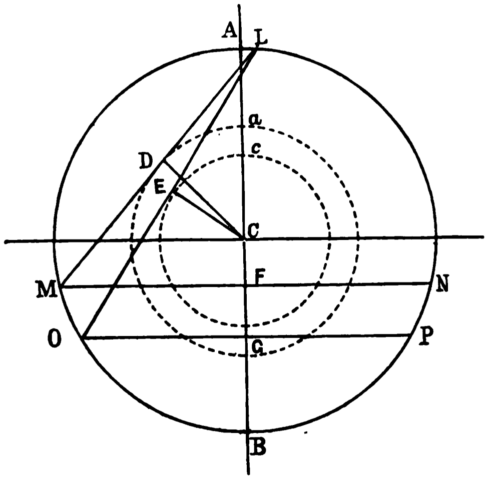
Note. The pressure on the guide has the same proportion to the pressure on the piston, as the length of the crank has to the length of the connecting rod.

Question. The piston is 49″ diameter, pressure 30 lbs. per square inch, length of crank 24″, and that of the connecting rod 8′ 4″, the guide block is 12″ by 10″; what is the greatest strain per square inch on the guide block? Make a sketch shewing the position of greatest strain.

$$\text{Greatest strain} = \frac{\cdot 7854 \times 49 \times 49 \times 30 \times 24}{12 \times 10 \times 100} = 113\cdot 1447 \text{ lbs.}$$

TO ALTER THE CUT OFF BY PINNING A PIECE ON TO THE VALVE, OR CHIPPING A PIECE OFF.

Suppose the slide has 8 inches travel, and that the cut off is $\frac{3}{4}$, and it be desired to alter it to $\frac{5}{8}$.



Let AB be a line 8 inches long, and C its centre.

From C with the radius CA describe a circle AOBP.

Let AF be 5 inches long, and AG 6 inches long; let AL be the lead of the slide.

Through F and G draw the lines MN and OP at right angles to AB, and let them meet the circle in the points M, O.

Draw the lines LM, LO, and CD, CE, perpendicular to them respectively.

From the centre C, with the radii CD, CE, describe circles meeting AB in *a* and *c* respectively.

Then *ac* is the thickness of the piece to pin on to the valve to alter the cut off from $\frac{3}{4}$ to $\frac{5}{8}$, or to chip off to make it from $\frac{5}{8}$ to $\frac{3}{4}$.

ON ENGINEER DRAWING.

The working drawings of parts of marine engines and boilers in the present work have all been prepared from actual pieces of machinery, and great care has been taken in order to have them correct, so that it is confidently expected they will tend to supply a great want felt by young engineers in preparing for the Board of Trade examinations.

The following hints may be useful to such persons :—

In drawing it is necessary to have a suitable drawing board, a T square, two set squares, one with an angle of 45°, the other with an angle of 60°, a box of instruments, India rubber, pencils, and drawing paper.

In shaping pencils for drawing, cut them with a flat edge like a chisel edge, as it lasts much longer than a round point, and makes the lines regular and of even thickness.

In commencing a drawing, whether from another drawing, or from a piece of machinery, begin with the centre lines ; as they are the most important lines in the drawing, and are usually represented by thin red lines.

Having drawn the centre lines, take all the principal dimensions of the more important and larger parts of the object from centre lines, and fill in the smaller details afterwards ; be very careful in transferring those dimensions to your own drawing, especially when working from different scales.

A few hints from a good teacher will be very beneficial to the learner, and by care, patience, and perseverance, he will ultimately become proficient in the art.

ON PLANS, ELEVATIONS, AND SECTIONS.

Engineer drawing is founded on the principles of *Perpendicular Projection*, in which the eye is supposed to be at an infinite distance from the plane of projection, so that all lines drawn from the eye to the object to be represented are perpendicular to the plane of projection. Referring to treatises on the subject for further information, we shall illustrate it as follows :—

If we stand on Sunderland bridge, and look at a ship passing underneath, then go alongside of her at the quay, then go ahead or astern of her, we find she has a very different appearance from these different points of view.

Conceive the ship to be out of the water, upright, and on an even keel, and a piece of paper placed at the bottom of the keel parallel to the horizen, and all the principal lines of the ship as they would appear if seen from an eye exactly above every point of them successively, to be drawn on the paper, then that drawing is called the *plan*.

Again, conceive that the ship is cut through the stem, keel, and sternpost, and a piece of paper is placed on the cut, and the principal lines of the ship are drawn on this paper as they would appear to an eye perpendicular to the paper at every point of every line and alongside of the ship, then this drawing is called the *elevation*, or sheer plan.

Again, conceive that the ship is cut through in the broadest part, square across, and a piece of paper is placed on the cut, and all the principal lines of the ship is drawn on the paper as they would appear to an eye perpendicular to the paper at every point of every line and ahead of the ship, then this drawing is called the *section*, or body plan.

A good idea of the planes of the plan, elevation, and section may be obtained by laying a book on the table, opening it so that one side of the back is perpendicular to the table, and placing another book at its end, so that it rests against the body of the book on the table, and also against its open back; and an object in the space contained by the two books, and the back of the one lying flat on the table might be represented in plan on the book lying on the table, in elevation on its back, and in section on the other book.

It is usual to represent the parts of machinery in plan, elevation, and section on the same paper. A line is drawn across the paper, and the plan is drawn below it, the elevation above, and the section at one side.

BOOKS PUBLISHED BY

CAPT. WM. C. BERGEN.

NAVIGATION,

PRICE SIXTEEN SHILLINGS.

ABRIDGEMENT OF NAVIGATION

PRICE TEN SHILLINGS.

OCEAN ROUTES,

PRICE TWO SHILLINGS.

A GREATLY

IMPROVED DUMB CARD,

Made and Sold by Messrs. BAHARIE and SON,

Graduated by Captain BERGEN, and fitted with Styles, Sights, Telescope, Clinometer, and Gimbals, as may be required.

PRICE £5, £3 & £2 ACCORDING TO QUALITY & FITTINGS.

In the opinion of Captain BERGEN, this Instrument is by far the best of any that he has seen, for finding the Deviation of the Compass.

CANDIDATES,

BOTH

SEAMEN & ENGINEERS,

PREPARED TO PASS THE

LOCAL MARINE BOARD

EXAMINATIONS,

BY

CAPT. WM. C. BERGEN

AND QUALIFIED ASSISTANTS,

Including his Son and a Practical Engineer,

AT HIS

NAUTICAL AND STEAM SCHOOL,

No. 7, Lawrence Street,

SUNDERLAND,

ABOVE THE SHOP OCCUPIED BY Messrs. BAHARIE & SON.

AN EVENING SCHOOL.

He also Teaches the following subjects :—Arithmetic, Algebra, Mensuration, Geometry, Trigonometry, Mechanics, Engineering Formulæ, Navigation, Deviation of the Compass and Differential and Integral Calculus.

In *Fig.* 7 the top card is good, but the bottom card has too much lead. In this case take a liner out from under the eccentric rod foot equal to half the lead, then the movements of both cards will be too soon; this will require the sheave shifted back a little.

Fig. 8 shews that the piston has been leaking in both the up and down stroke at a certain part, or that the cylinder is slack in the middle, as shown by the rise in the back pressure.

In *Fig.* 9 on the top card at the steam corner there is a loop. This is owing to the Indicator piston shooting straight up on admission of steam. While the piston of the engine is for a moment stationary on passing the centre, when the engine piston begins to move this line falls suddenly, forming the loop; the bottom card will be observed to have too much compression, thus wasting power. To remedy this, notice that the exhaust opens late; therefore if a piece is chipped off the exhaust edge of the valve, it will open sooner and close later, doing away with so much compression.

Fig. 10 shews that the slide has been leaking on the bottom face. I[illegible] will be seen by the rise of the pressure at *d* that fresh steam has bee[illegible] admitted after it has been cut off.

Fig. 11 shews by the steam lines slanting instead of being horizont[illegible] that the steam has been throttled, or that the pipes or ports are to[illegible] small for the cylinder.

Fig. 12 shews a pair of cards throttled by the link at 42 strokes p[illegible] minute. In these diagrams nearly the whole areas are below the atm[illegible]spheric line, but on the left hand corner of one of the Figures a loop [illegible] formed, which often appears in engines employing the link, the meanin[illegible] of which it is necessary to explain. The extreme point of the diagra[illegible] in every instance answers to the length of the stroke, and if the stea[illegible] is put up in the cylinder by the exhaust being closed before the end [illegible] the stroke, or if steam be allowed to enter before the end of the strok[illegible] the pencil will rise to its highest point before the stroke is ended, and the paper on the barrel continues to move onward, the upper part of t[illegible] loop is formed. If the pressure within the cylinder when the pist[illegible] returns were to be precisely the same as when the piston advanc during this part of the stroke, the loop would be narrowed to a li[illegible] But as the advance of the piston when the valve is very little op[illegible] somewhat compresses the steam, and at its recession, when the valve is very little open, causes it to be wire-drawn. The pressure while the piston advances and retires through this small distance, although the cylinder is open to the boiler by means of a small orifice, will not be precisely the same, and the higher pressure will form the upper part of the loop, while the lower part will be formed by the lower pressure. By following the outline of the left hand diagram, it will be seen that the steam begins to be compressed within the cylinder when about three-fourths of the stroke has been completed, and the pencil consequently begins to rise somewhat above its lowest point; but as the vapour within the cylinder is very rare, the rise is very little until the

engines are good, showing all the different grades of expansion clearly, and especially the difference in the pressures in the low pressure cylinders, owing to the one being jacketed and the other not.

Fig. 17. Cards taken from a compound engine. On the low pressure card vibration of the Indicator pencil will be observed, caused by the Indicator piston being too tight, or the Indicator spring being too stiff.

Figs. 18 and 19. The irregular lines and small jumps seen on these cards are also caused by the vibration of the Indicator pencil through the spring being too stiff.

Figs. 20 and 21 are specimens of Indicator cards taken from a compound engine. In Fig. 20 the steam is cut off at one quarter the stroke. Fig. 21 the steam was cut off at ⅜ of the stroke. These cards were taken from an engine employed in the making of gas, the fuel used being coke in Fig. 21, the consumption being 4·8lbs. per I.H.P. In Fig. 20 Welsh coal was used, the consumption being reduced to 2·8lbs. per I.H.P.

Fig. 22. Cards taken from a pair of compound screw engines, with the indicated horse power worked out.

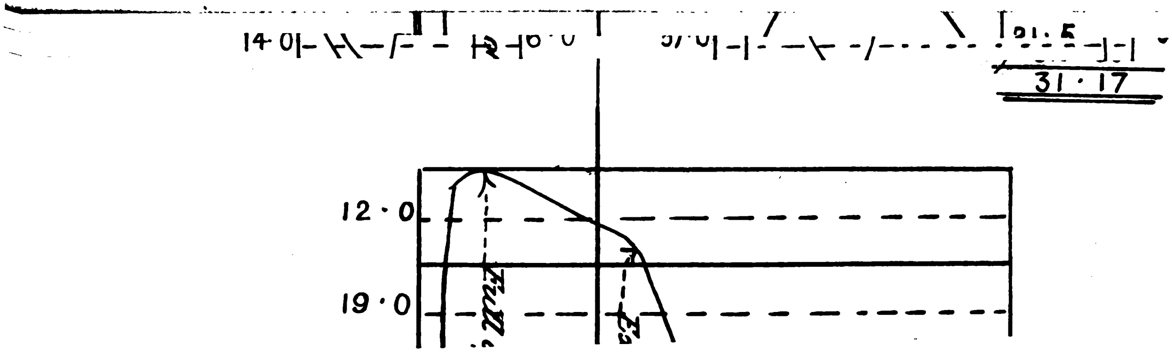
Fig. 23. Cards from a pair of compound screw engines, with the indicated horse power worked out. The process is as follows;—Divide the cards into ten equal parts, as shewn in Figs. 22 and 23. The advantage of dividing it into ten parts instead of seven or eight parts is that the division by ten is accomplished by merely shifting the position of the decimal point; a division of ten parts is quite accurate enough for all practical purposes. Measure the width of the card in the middle of each division, as shown by the dotted lines; add the sum together and divide by ten, or, as stated before, shift the decimal point one figure to the front, which amounts to the same thing. This will equal the mean pressure on that side of the piston. Proceed with the other card in the same way. Having got the mean pressure on each side of the piston, add both together and divide by two; the sum of this equals the mean pressure in the cylinder. Then proceed as follows:—

$$\frac{\text{area of cylinder} \times \text{mean pressure} \times \text{piston speed per min.}}{33000} = \text{the}$$

indicated horse power obtained from that cylinder. The revolutions per minute multiplied by twice the length of stroke in feet equals the piston speed per minute.

Fig. 24. Cards from the cylinder of an oscillating paddle wheel engine, the diameter of the cylinder 54", stroke 6' 0".

Fig. 25. Diagrams from a pair of compound screw engines, built on the Tyne.


14·0
31·17
12·0
19·0
Full
Ea

high pressure cylinders being 22" dia., and low pressure cylinders 38" dia., the stroke being 6′ 0". These engines drive feathering paddle wheels 21′ 0" dia., each wheel having 16 floats 10′ 0" × 2′ 6" broad.

Fig. 36. Cards taken from a pair of compound screw engines having the cylinders and covers jacketed, high pressure slide cutting off at ·7 of the stroke, and the low pressure slide cutting off at ·5 of the stroke.

Fig. 37 shows cards taken from a compound screw engine working at full gear, and also with the gear four turns in, showing a very light consumption of coal. These cards speak for themselves, and require no comment.

Fig. 38. Cards taken from a single cylinder engine used for driving the machinery in a cotton mill in Lancashire. The consumption of coal per I.H.P. is also shown.

Fig. 39 shews diagrams taken from a three-cylinder compound screw engine. The high pressure cylinder is placed above the intermediate one, the same piston rod serving for both cylinders. The low pressure cylinder is placed alongside of the intermediate one. The remainder of the particulars will be seen on the cards.

Fig. 40. Diagrams from locomotive engines. In No. 1 card it will be seen that the admission is small, by the slight falling off in the steam line. This could be remedied by increasing the length of the port, or the travel of the valve. No. 2 card is much better in this respect, the steam line running out straight, and showing a full and even pressure until the point of cut off is reached. Diagram No. 3 shows an enormous amount of compression when linked up; while No. 4 is linked up further than No. 3, and is much better in this respect, as seen by the compression line running very little above the steam line.

Figs. 41 and 42 are specimens of Friction diagrams. Fig. 41 is taken from a screw engine, having the propeller shaft disconnected at the first coupling. Fig. 42 is taken from a paddle wheel engine, with the paddle wheels disconnected. It is seldom that friction diagrams are taken, unless for experiment, as there is very great risk attending the taking of them. For all practical purposes the friction is usually taken at 1lb, pres. per square inch on the piston for large engines, and 2lbs. for small engines. The friction of large engines is less in proportion than small engines.

The latest experiment of this kind was carried out with the engines of H.M. twin screw despatch vessel "Iris." This vessel is fitted with two sets of engines, each set having two high pressure cylinders 41 inches diameter, and two low pressure cylinders 75 inches diameter, having a stroke of 3′ 0". Each set of engines were kept running steadily while two sets of diagrams were taken. The port engine running at 87·5 revolutions per minute gave 202 indicated horse power, and the starboard engine at 90·5 revolutions per minute gave 196 indicated horse

FIG. 4

SCALE $\frac{1}{16}$

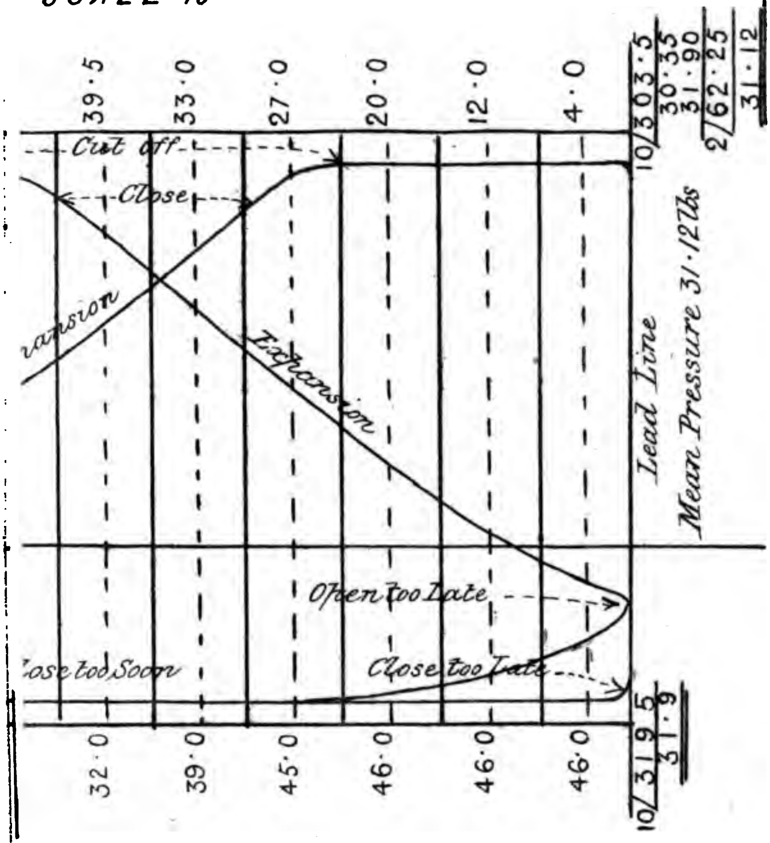


FIG 9

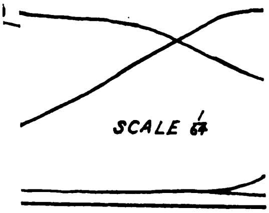


FIG 10

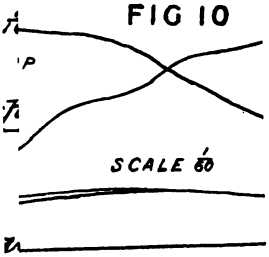


FIG 11

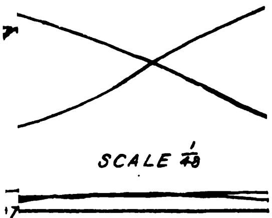
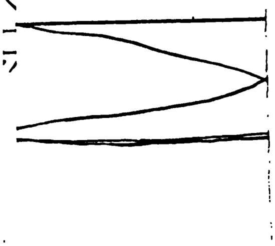
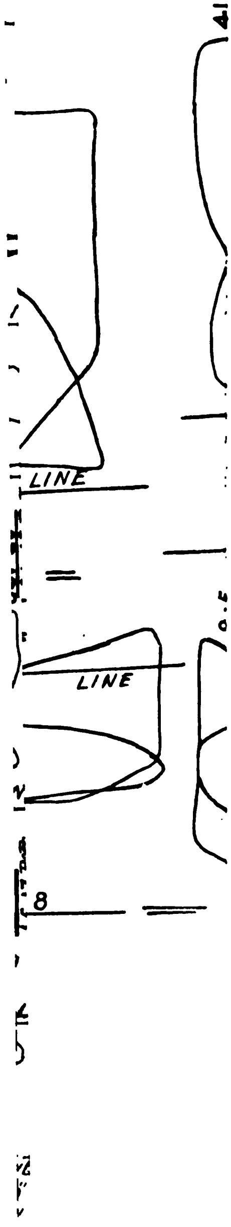
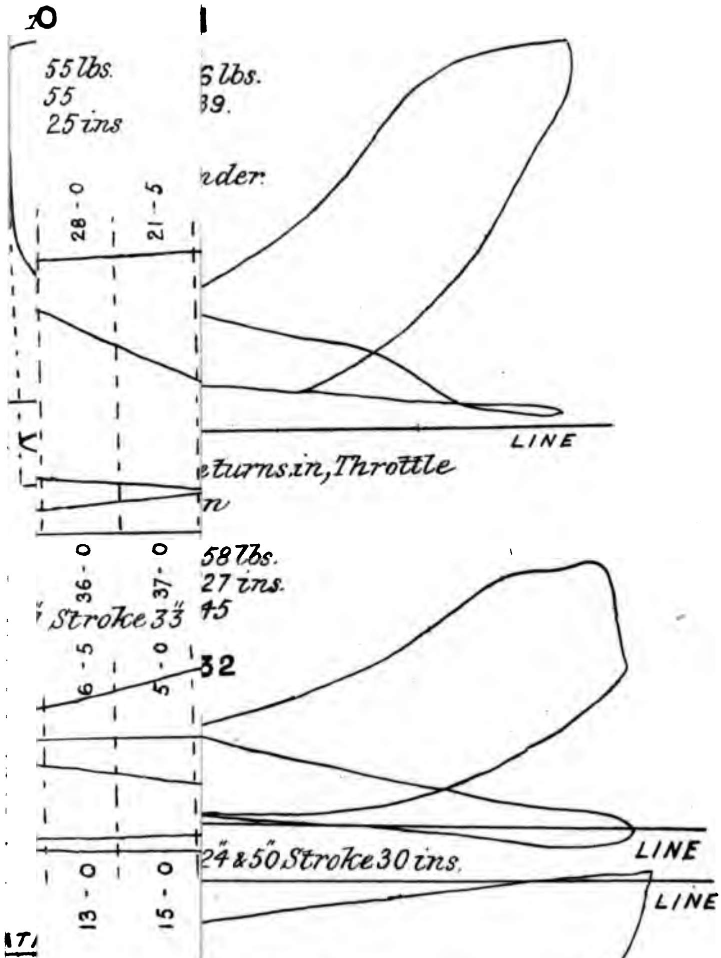


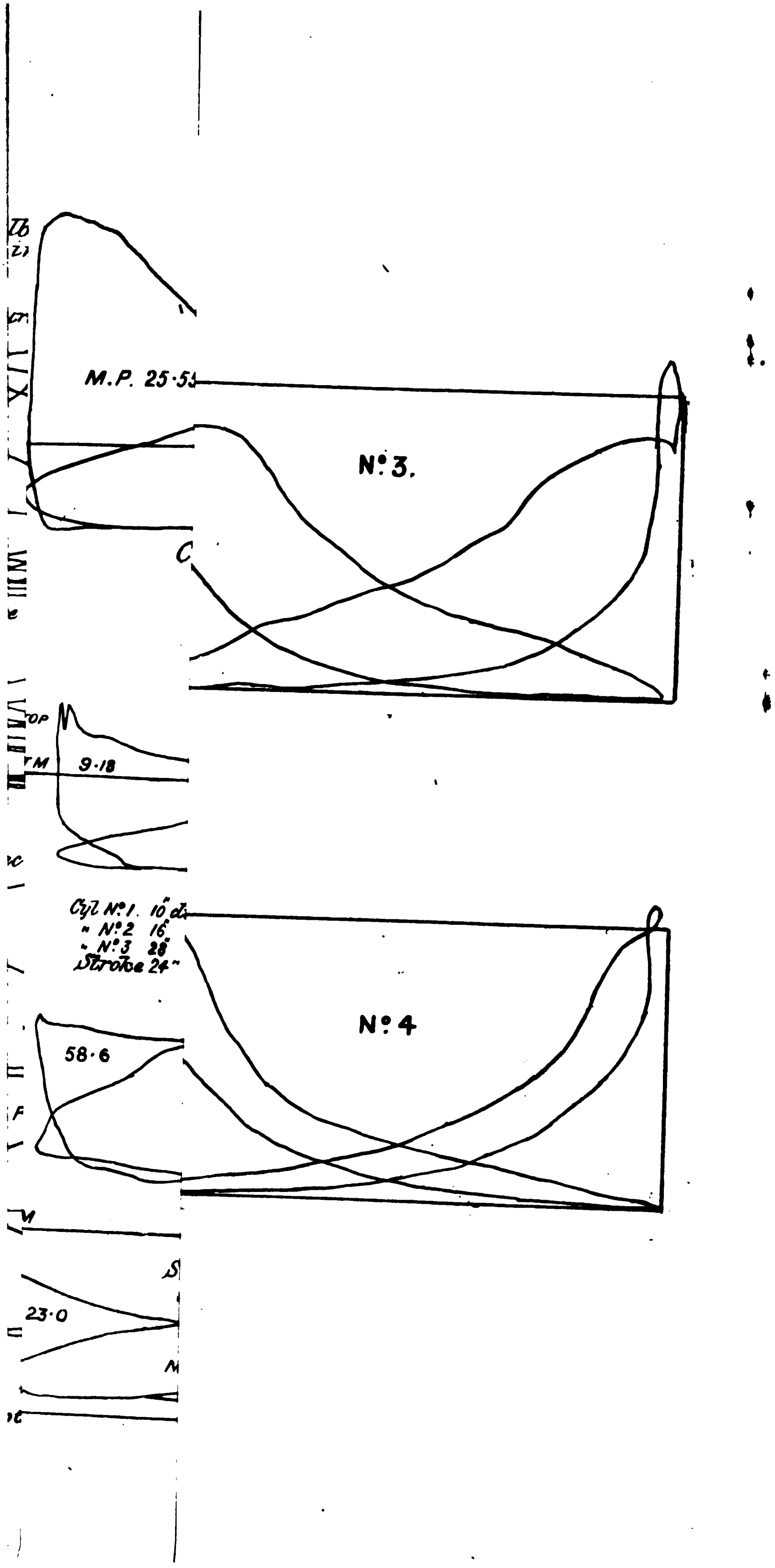
FIG 12

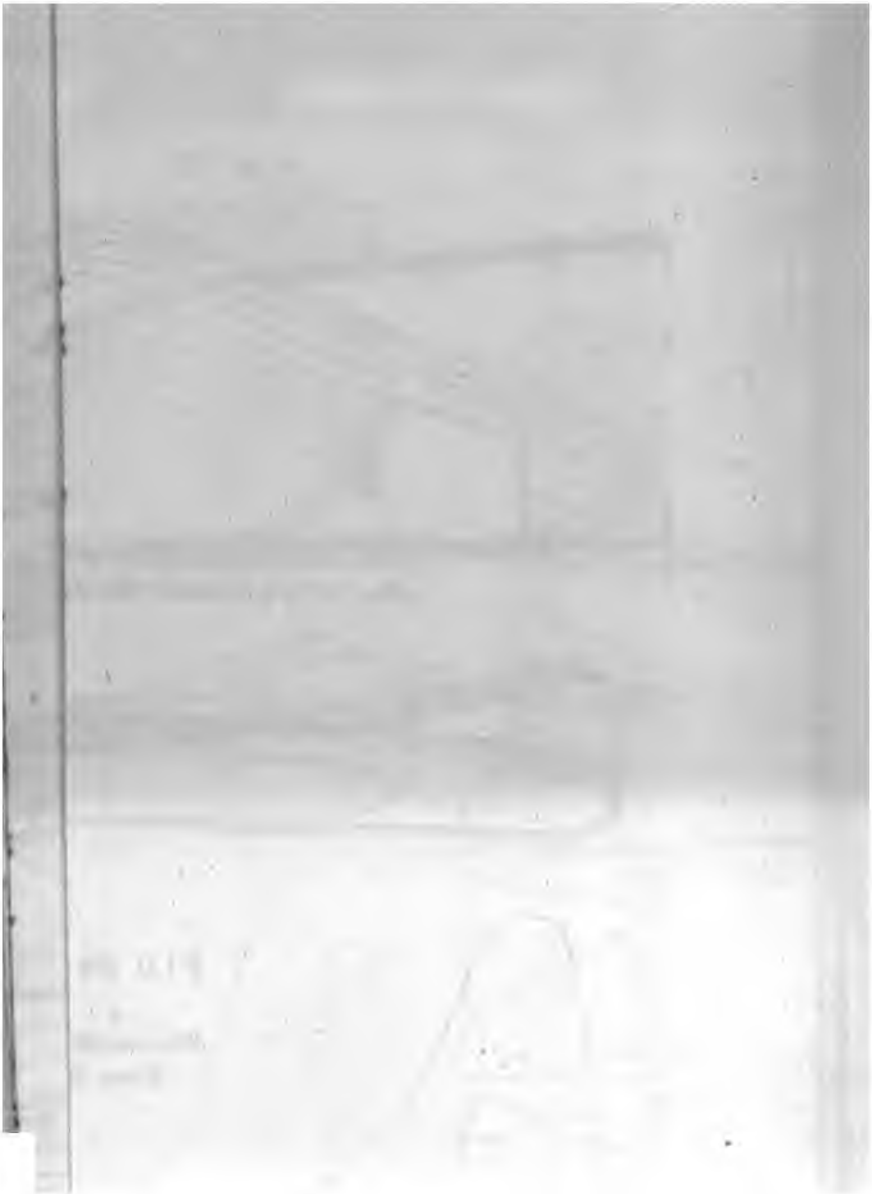



41
LINE
LINE
0.5
8



Throttled by the link.


M.P. 25·5
N°3.
9·18
Cyl N°1. 10" d
" N°2 16"
" N°3 28"
Stroke 24"
N°4
58·6
23·0

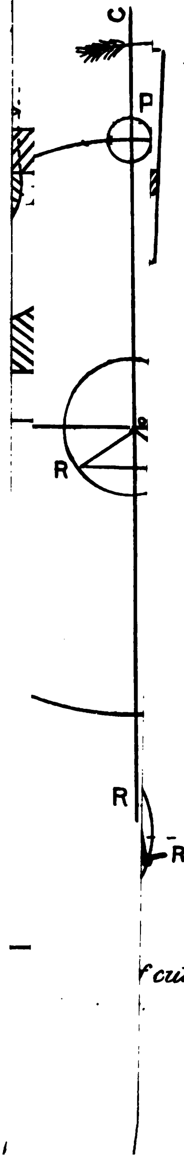


NS=

down Stroke.. 16¼"
up Stoke...... 14¼"

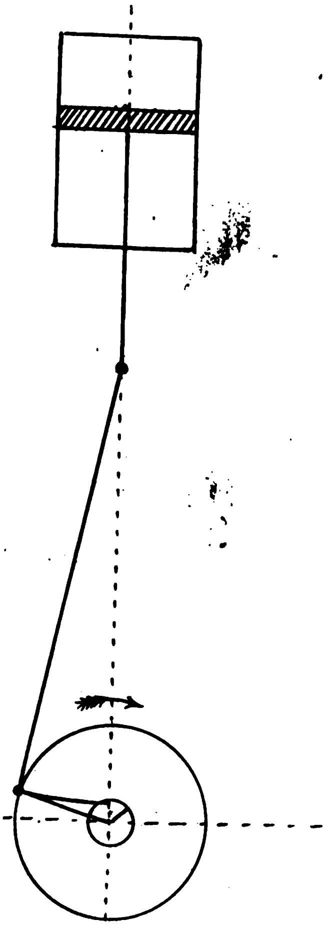
le ½" = 1 Foot=

Fig.

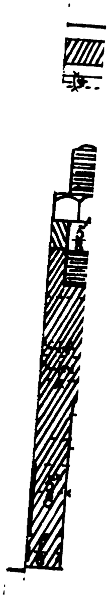


f cut off

Fig 4



Piston at point of cut off
up Stroke



ON ENGINEER DRAWING.

The working drawings of parts of marine engines and boilers in the present work have all been prepared from actual pieces of machinery, and great care has been taken in order to have them correct, so that it is confidently expected they will tend to supply a great want felt by young engineers in preparing for the Board of Trade examinations.

The following hints may be useful to such persons :—

In drawing it is necessary to have a suitable drawing board, a T square, two set squares, one with an angle of 45°, the other with an angle of 60°, a box of instruments, India rubber, pencils, and drawing paper.

In shaping pencils for drawing, cut them with a flat edge like a chisel edge, as it lasts much longer than a round point, and makes the lines regular and of even thickness.

In commencing a drawing, whether from another drawing, or from a piece of machinery, begin with the centre lines ; as they are the most important lines in the drawing, and are usually represented by thin red lines.

Having drawn the centre lines, take all the principal dimensions of the more important and larger parts of the object from centre lines, and fill in the smaller details afterwards ; be very careful in transferring those dimensions to your own drawing, especially when working from different scales.

A few hints from a good teacher will be very beneficial to the learner, and by care, patience, and perseverance, he will ultimately become proficient in the art.

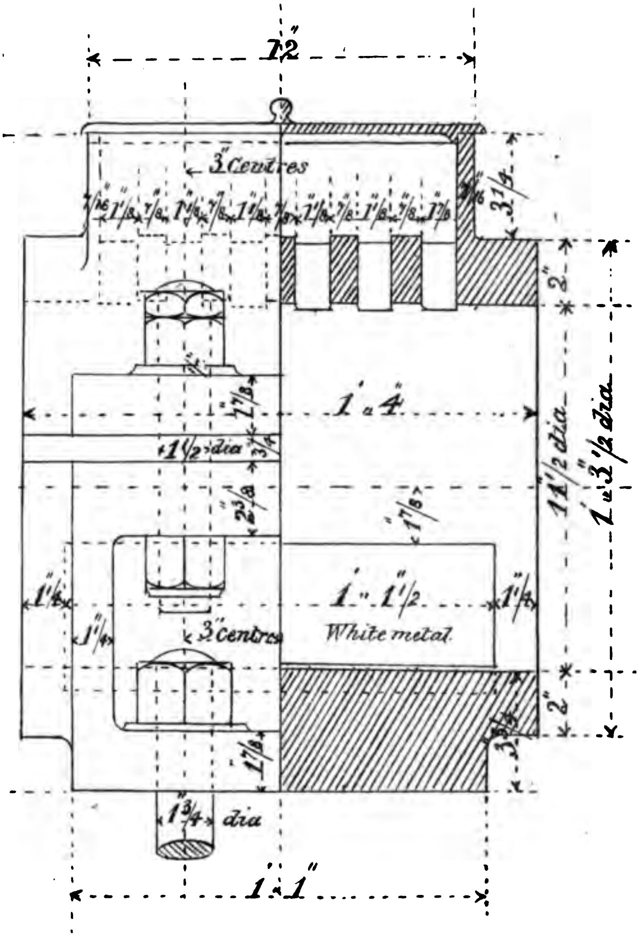
ON PLANS, ELEVATIONS, AND SECTIONS.

Engineer drawing is founded on the principles of *Perpendicular Projection*, in which the eye is supposed to be at an infinite distance from the plane of projection, so that all lines drawn from the eye to the object to be represented are perpendicular to the plane of projection. Referring to treatises on the subject for further information, we shall illustrate it as follows :—

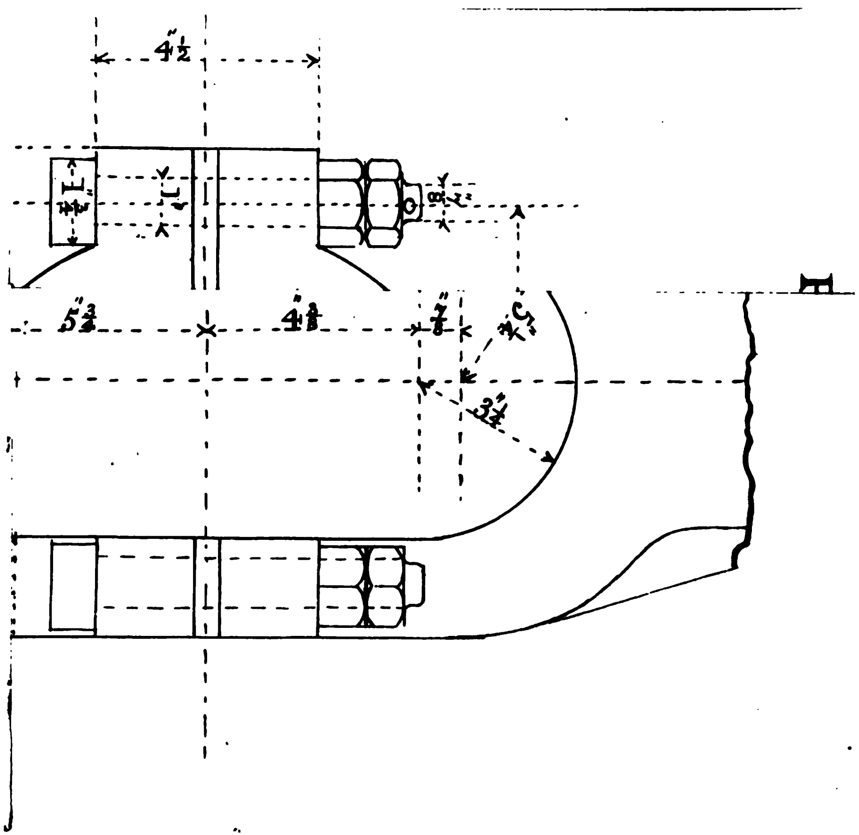
If we stand on Sunderland bridge, and look at a ship passing underneath, then go alongside of her at the quay, then go ahead or astern of

RING

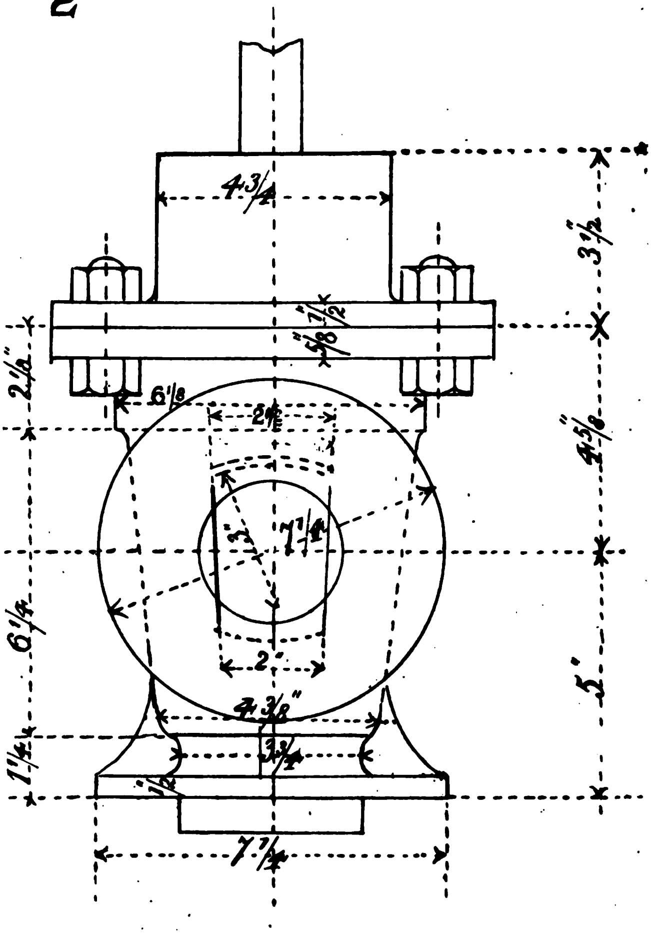
foot.



12"
3" Centres
7/16
1 1/8
7/8
1 1/8
7/8
1 1/8
7/8
1 1/8
7/8
1 1/8
7/8
1 1/8
7/16
3 1/4
2"
1' 4"
1 7/8
1 1/2 dia
3/4
2 3/8
1 7/8
1' 1 1/2
White metal
1 1/4
1 1/4
1 1/4
3" centres
2"
3 1/4
1 7/8
1 3/4 dia
1' 1"
11 1/2 dia
1' 3 1/2 dia


4½"
1¾"
1"
⅞"
5¾"
4⅛"
⅞"
5¼"
3¼"

2

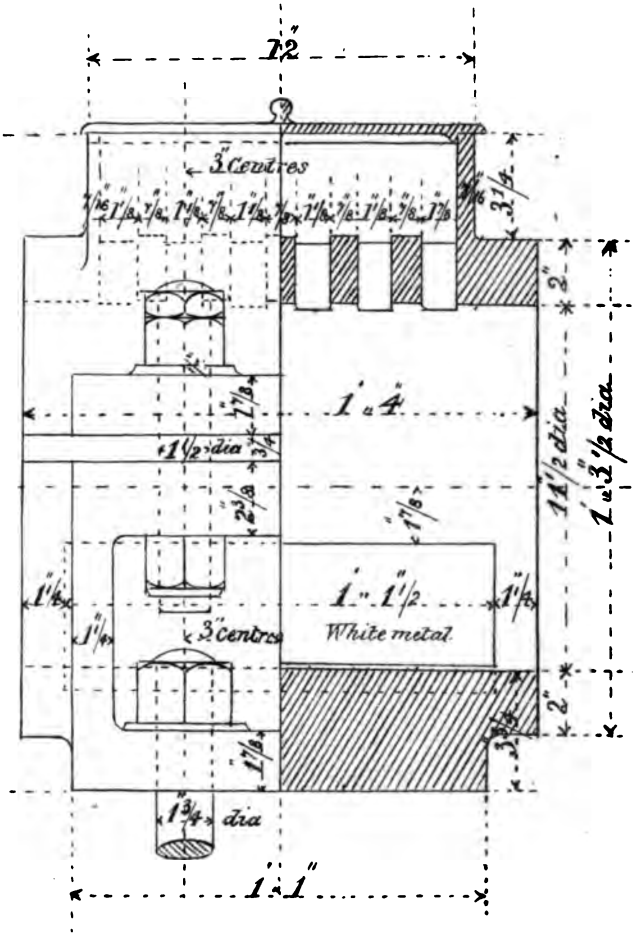


BOTTOM BLOW OFF COCK

SCALE = 3 Inches per foot.

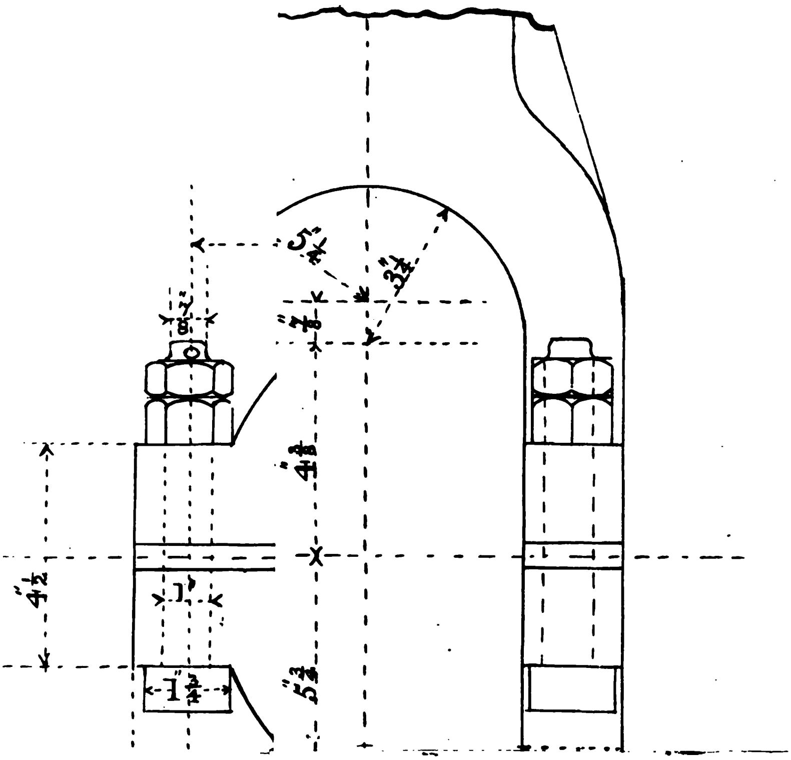
RING

foot.

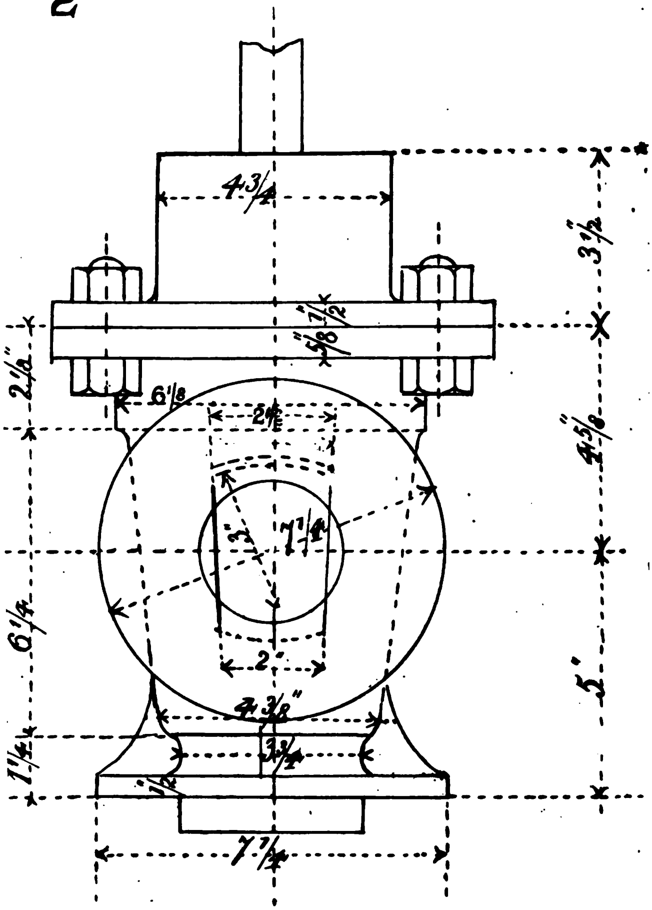


12"
3" Centres
7/16 1 1/8 7/8 1 1/8 7/8 1 1/8 7/8 1 1/8 7/8 1 1/8 7/8 1 1/8 7/8 1 1/8
9/16
3 1/4
2"
1' 4"
1 7/8
1 1/2 dia
3/4
2 3/8
1 7/8
11 1/2 dia
1' 3 1/2 dia
1 1/4
1 1/4
1' 1 1/2
White metal
1 1/4
3" centres
1 7/8
3 3/4
2"
1 3/4 dia
1' 1"

F



2



BOTTOM BLOW OFF COCK

SCALE = 3 Inches per foot.